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Simulator Sickness in the AH-1S (Cobra) Flight Simulator

By

Daniel W. Gower, Jr.

Biodynamics Research Division

and

Jennifer Fowlkes

Essex Corporation
Orlando, Florida

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United States Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-5292

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Reviewed:

DANIEL W. GOWER, JR.
LTC, MS
Director, Biodynamics Research Division

J. D. LaMOTHE, Ph.D.
COL, MS
Chairman, Scientific Review Committee

Released for publication:

DAVID H. KARNEY
Colonel, MC
Commanding

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The U.S. Army Aeromedical Research Laboratory conducted field studies of operational flight simulators to assess the incidence and severity of simulator sickness. Simulator sickness here refers to the constellation of motion sickness related symptoms that occur in simulators due to visual representation, motion base representation, or combination of the two representations of flight. The incidence rates and relative frequency of specific symptoms are presented. Correlational factors such as recent simulator experience, current state of health, overall flight experience, mission scenario, and flight dynamics are presented. This report ranks the Army's flight simulators in comparison to the 10 Navy simulators studied by the Naval Training Systems Center, Orlando, FL. The study further reinforces the need for studies to understand perceptual rearrangement, adaptation/readaptation, and pilot susceptibility to the effects of simulation. Design criteria for simulators, as well as those training guidelines necessary to cope with this phenomenon also must be addressed.

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Introduction

U.S. Army's involvement with simulator sickness

Prior to the actual fielding of the AH-64 Apache combat mission simulator (CMS) at U.S. Army installations, training of Apache pilots was conducted at the Singer Link facility in Binghamton, New York. Anecdotal information indicated some of the pilots and instructor operators (IO) were experiencing symptoms of simulator sickness resembling those reported in U.S. Navy and U.S. Coast Guard systems. Some students took Dramamine™ to alleviate their symptoms. In May 1986, documentation of the problem reached the U.S. Army Aeromedical Research Laboratory (USAARL) at Fort Rucker, Alabama. In July 1986, the Aviation Training Brigade at Fort Rucker formed a study group to examine the Apache training program. One of the issues studied was simulator sickness.

A survey of existing training records and a literature search were conducted by USAARL in August 1986. Training records of 115 students from the CMS showed that 7 percent of the students had sufficient symptoms to warrant a comment on their grade slips. The literature search led USAARL investigators to visit the Naval Training Systems Center (NTSC) in Orlando, Florida. From that association has grown a working relationship geared to capitalize on lessons learned from past research and expand the database of simulator sickness studies. As part of that search, it also was discovered that a U.S. Army flight surgeon had conducted an independent survey of the incidence of simulator sickness in the AH-1 Cobra flight weapons simulator (FWS) located in Germany (Crowley, 1987).

In the report to the Army study group, it was recommended a problem definition study be conducted to ascertain more accurately the scope and nature of the problem of simulator sickness in the Apache CMS. The request for that study was received from the Directorate of Training and Doctrine, Fort Rucker, Alabama, in February 1987. The protocol for the study was approved by the USAARL Scientific Review Committee on 4 May 1987. USAARL Report No. 88-1 documents the results of that first study.

As reported in Baltzley et al. (1989), 25 percent of those reporting aftereffects indicated their symptoms persisted longer than 4 hours while 8 percent lasted 6 hours or longer. The Army data presented in that report was contaminated with effects experienced by Apache pilots who had previous experience with the Cobra FWS. Problems with other Army simulator systems also have been documented since the first study. Most notable, aviators training in the new AH-1 Cobra simulator were complaining of postsimulator exposure aftereffects which outlasted the training period by several hours. The need for further studies was apparent.

In September 1988, USAARL received a request from the Directorate of Training and Doctrine at the U.S. Army Aviation Center at Fort Rucker, Alabama, requesting further field studies to assess the incidence of simulator sickness in the remaining visually-coupled flight simulators. The protocol was approved 19 October 1988 and collection of data began in January 1989. This report documents the results of the data collected at the AH-1S simulator site at Fort Rucker, Alabama.

The nature of simulator sickness

Simulator sickness is considered to be a form of motion sickness. Motion sickness is a general term for the constellation of symptoms which result from exposure to motion or certain aspects of a moving environment (Casali, 1986), although changing visual motions (Crampton and Young, 1953; Teixeira and Lackner, 1979) may induce the malady. Pathognomonic signs are vomiting and retching; overt signs are pallor, sweating, and salivation; symptoms are drowsiness and nausea (Kennedy and Frank, 1986). Postural changes occur during and after exposure. Other signs (Colehour and Graybiel, 1966; McClure and Fregly, 1972; Money, 1970; Stern et al., 1987) include changes in cardiovascular, respiratory, gastrointestinal, biomedical, and temperature regulation functions. Other symptoms include general discomfort, apathy, dejection, headache, stomach awareness, disorientation, lack of appetite, desire for fresh air, weakness, fatigue, confusion, and incapacitation. Other behavioral manifestations influencing operational efficiency include carelessness and incoordination, particularly in manual control. Differences between the symptoms of simulator sickness and more common forms of motion sickness are that in simulator sickness visual symptoms tend to predominate and vomiting is rare.

Advancing engineering technologies permit a range of capabilities to simulate the real world through very compelling kinematics and computer-generated visual scenes. Aviators demand realistic simulators. However, this synthetic environment can, on occasion, be so compelling that conflict is established between visual and vestibular information specifying orientation (Kennedy, 1975; Oman, 1980; Reason and Brand, 1975). It has been hypothesized that in simulators, this discrepancy occasions discomfort, or "simulator sickness" as it has been labeled, and the cue conflict theory has been offered as a working model for the phenomenon (Kennedy, Berbaum, and Frank, 1984). In brief, the model postulates the referencing of motion information signaled by the retina, vestibular apparatus, or sources of somatosensory information to "expected" values based on a neural store which reflects past experience. A conflict between expected and experienced flight dynamics of sufficient magnitude can exceed a pilot's ability to adapt, inducing in some cases simulator sickness.

The U.S. Navy conducted a survey of simulator sickness in 10 flight trainers where motion sickness experience questionnaires and performance tests were administered to pilots before and after some 1200 separate exposures (Kennedy et al., 1987b). From these measures on pilots, several findings emerged: (a) Specific histories of motion sickness were predictive of simulator sickness symptomatology; (b) postural equilibrium was degraded after flights in some simulators; (c) self-reports of motion sickness symptomatology revealed three major symptom clusters: Gastrointestinal, visual, and vestibular; (d) certain pilot experiences in simulators and aircraft were related to severity of symptoms experienced; (e) simulator sickness incidence varied from 10 to 60 percent; (f) substantial perceptual adaptation occurs over a series of flights; and (g) there was almost no vomiting or retching, but some severe nausea and drowsiness.

Another recent study suggests that inertial energy spectra in moving base simulators may contribute to simulator sickness (Allgood et al., 1987). The results showed the incidence of sickness was greater in a simulator with energy spectra in the region described as nauseogenic by the 1981 Military Standard 1472C (MIL-STD-1472C) and high sickness rates were experienced as a function of time exceeding these very low frequency (VLF) limits. Therefore, the U.S. Navy has recommended, for any moving-base simulator which is reported to have high incidences of sickness, frequency times acceleration recordings of pilot/simulator interactions should be made and compared with VLF guidelines from MIL-STD-1472C. However, in those cases where illness has occurred in a fixed-base simulator, other explanations and fixes are being sought.

Of particular concern in the area of safety are simulator induced posteffects. Gower et al. (1987) showed that as symptoms decreased over flights for pilots training in the AH-64 CMS, suggesting that pilots were adapting to the discordant cues in the simulator, postflight ataxia increased suggesting that pilots were having to readapt to the normal environment. Such readaptation phenomena parallel findings from other motion environments including long-term exposure onboard ships (Fregly and Graybiel, 1965), centrifuges (Fregly and Kennedy, 1965) and space flight (Homick and Reschke, 1977). For example, Graybiel and Lackner (1983) found 54 percent of the posteffects of parabolic flight lasted longer than 6 hours and 14 percent lasted 12 hours or more. In their report, the primary symptoms reported were dizziness and postural disequilibrium. The similarity of symptomatology between these experiences leads us to believe simulator sickness poses safety of flight issues which cannot be ignored.

Materials

Description of the aircraft system

The AH-1S helicopter is a tandem seat, two place (pilot and gunner), single engine aerial weapon platform (TM 55-1520-236-10) built by Bell Helicopter Corporation. The fuselage is constructed of aluminum alloy skins and aluminum, titanium and fiberglass honeycomb panel construction. There are two main beams in the fuselage which support the cockpit, landing gear, wings, engine, pylon assembly, fuel cells, and tailboom. The basic construction is called a box-beam structure due to the use of honeycomb deck panels and bulkheads attached to these two main beams. The nose section incorporates the turret system and its telescopic sight unit (TSU).

Mounted on each side of the fuselage are two short 129-inch wings which are used to provide additional lift and to support the stores pylons. The inside pylons are fixed and the outboard pylons are hydraulically actuated. The tailboom is a tapered semimonocoque structure which supports the cambered fin, tail skid, elevators, tail rotor, and rotor drive system. The principal dimensions of the aircraft are as shown in Figure 1.

The aircraft has a two-bladed main rotor system constructed of metal bonded assemblies for the B540 rotor system or of glass fiber/epoxy resin assemblies in the K747 rotor system. The engine system is a single T53-L-703 engine which has been derated due to the transmission capabilities. The main landing gear is a skid system consisting of two aluminum lateral mounted crosstubes and two aluminum longitudinal skid tubes.

Armament for the AH-1 is stored in either the wing stores or the turret. The AH-1 is configured in one of 20 armament configurations (Figure 2). The following types of armament can be installed: 20 mm cannon from the M-197 automatic gun located in the turret (Figure 3), tube launched, optically tracked, wire command link missile (TOW) located on the outboard pylons of the wing stores (Figure 4), M18 or M18A1 7.62 mm machine gun located on the wing stores (Figure 5), M158 or XM260 7 tube rocket launchers, or M200A1, XM227, or XM261 19 tube rocket launchers (Figure 6). The TOW missile system is used as a heavy antitank/ assault weapon. The system uses optical and infrared (IR) means to track a target and guide the missile. The TOW is effective in the daylight but night use is limited unless flares are used to illuminate the target. The rocket management subsystems are light antipersonnel assault weapons which can utilize the 2.75-inch folding fin aerial rocket warheads. The self-contained wing gun pod houses the 7.62 mm machine gun which is capable of carrying a maximum of 1500 rounds and firing those rounds at a rate of 2000 or 4000 rounds per minute depending on the system installed. The universal turret system provides for the positioning, sighting, and firing of the M197 20 mm gun. The system can slew the turret 110 degrees left and right and a maximum of 21 degrees up and 50 degrees down. The turret fires in bursts of 16 rounds or in a maximum continuous burst of 730 rounds depending on the pilot's input.

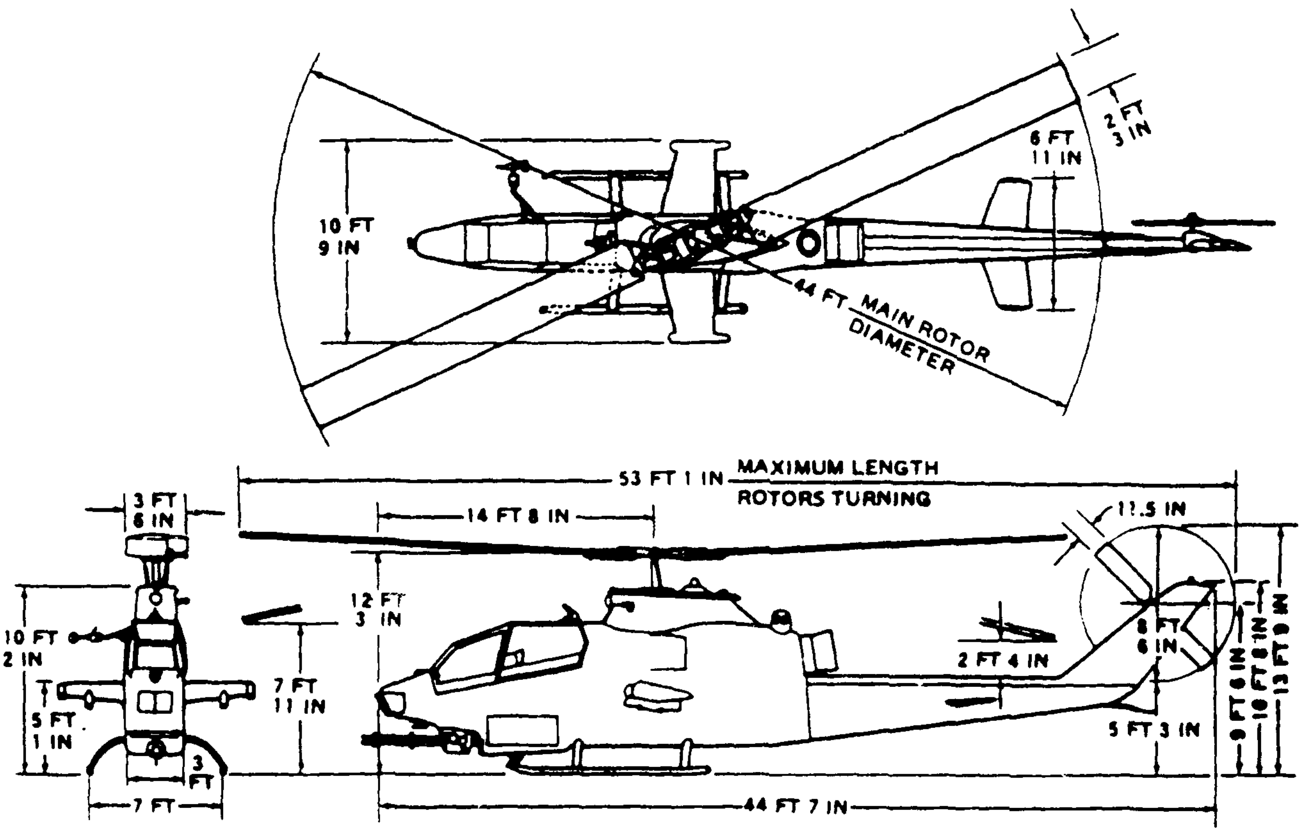


Figure 1. Principal dimensions.

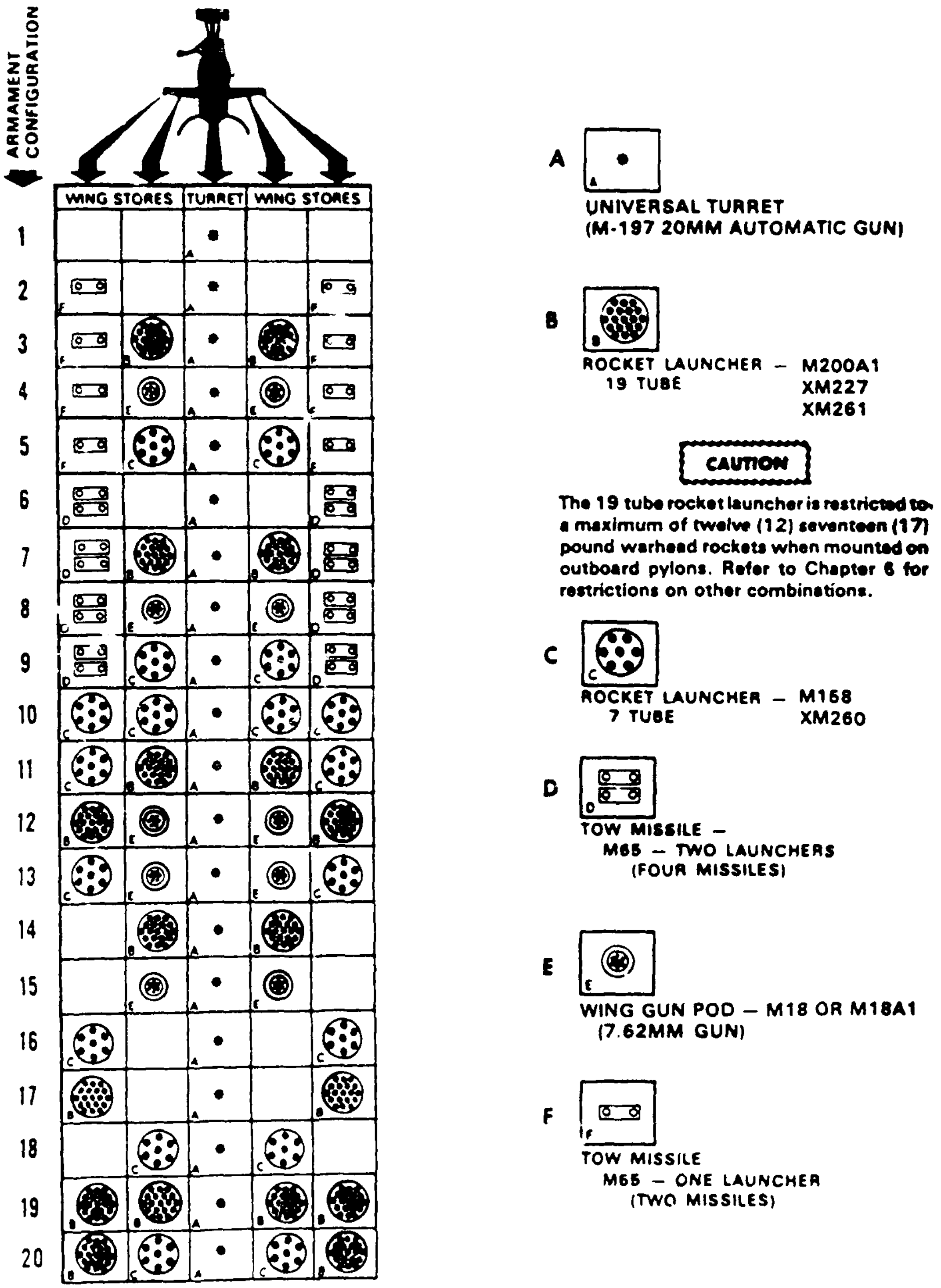


Figure 2. Authorized armament configuration.

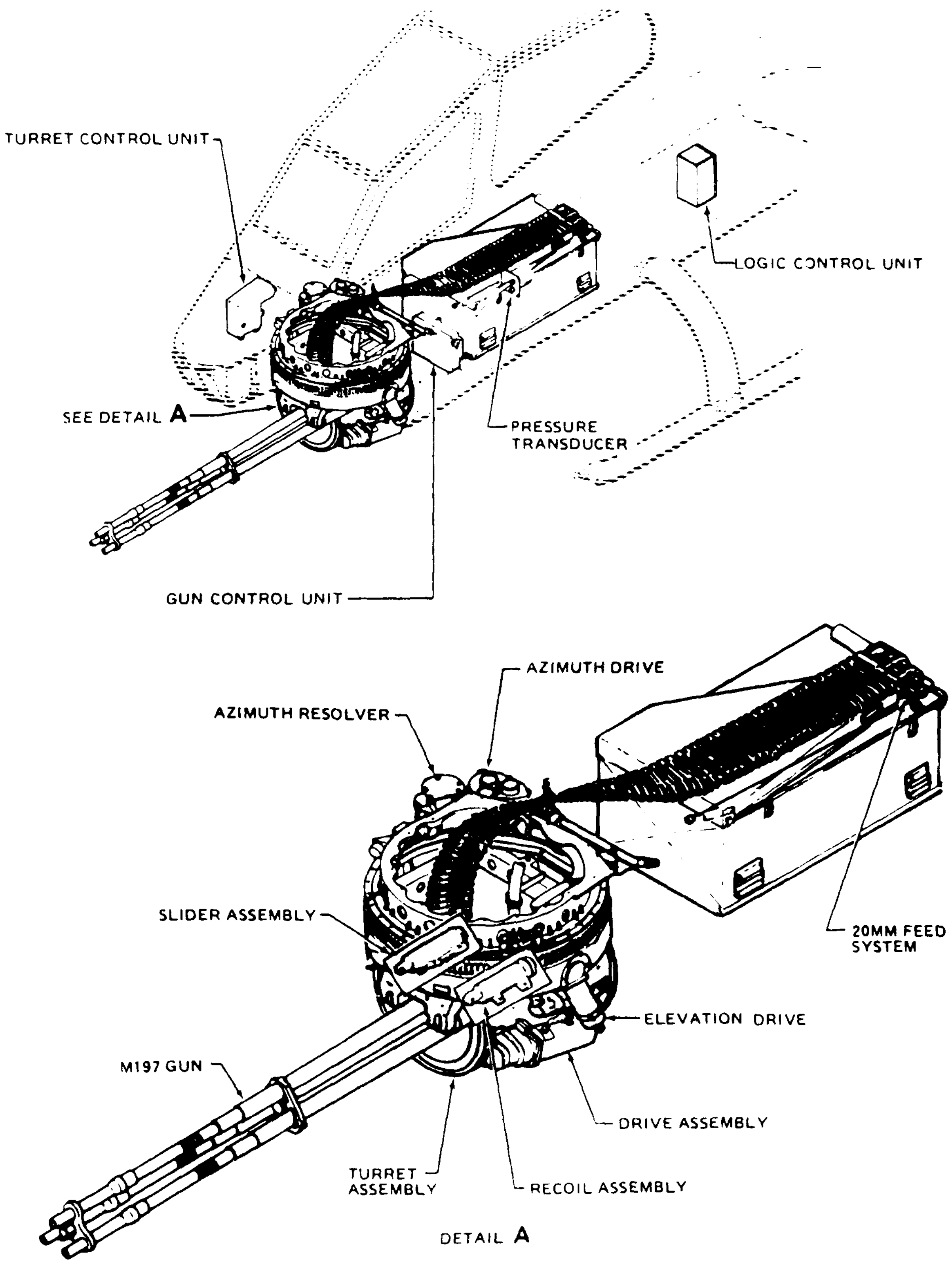
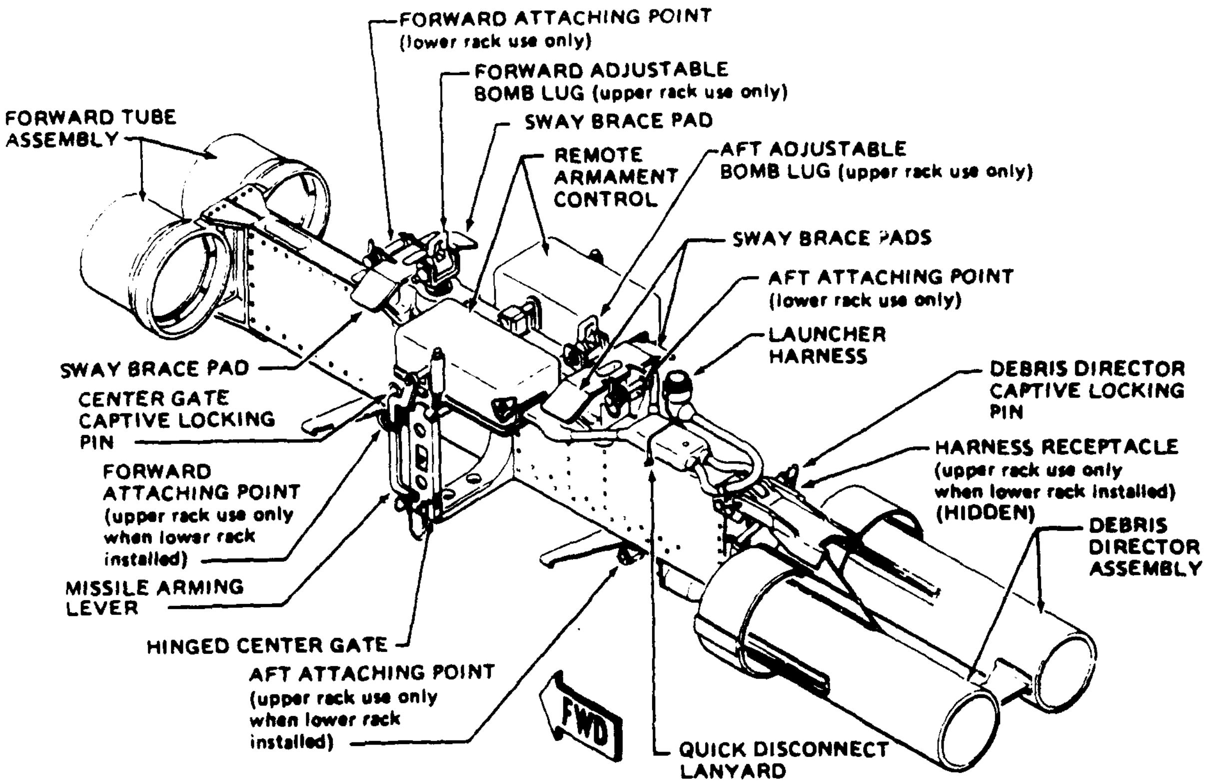


Figure 3. Universal turret components.



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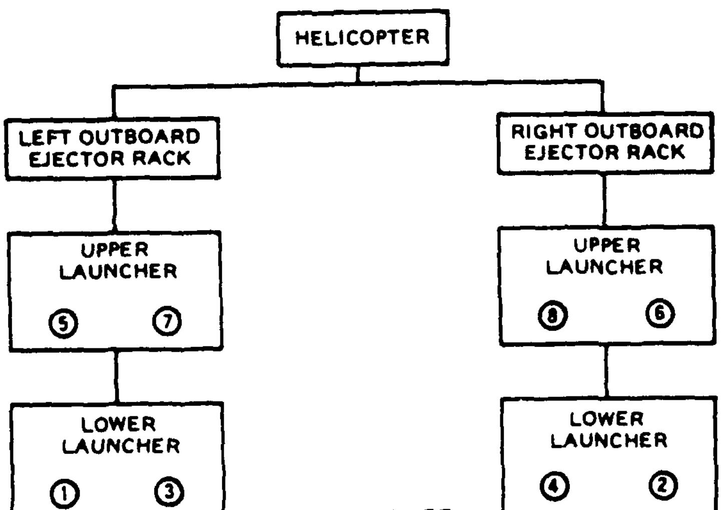

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Figure 4. TOW missile launcher.

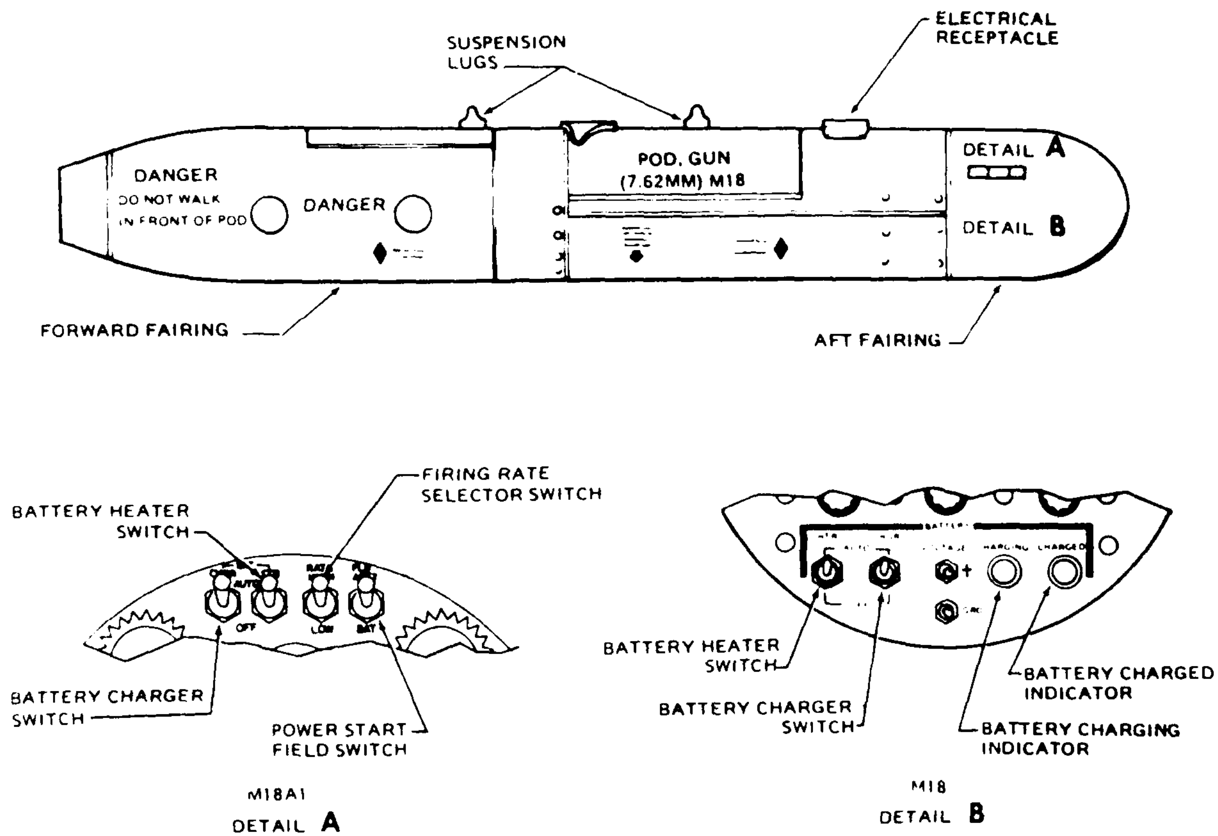


Figure 5. Wing gun pod.

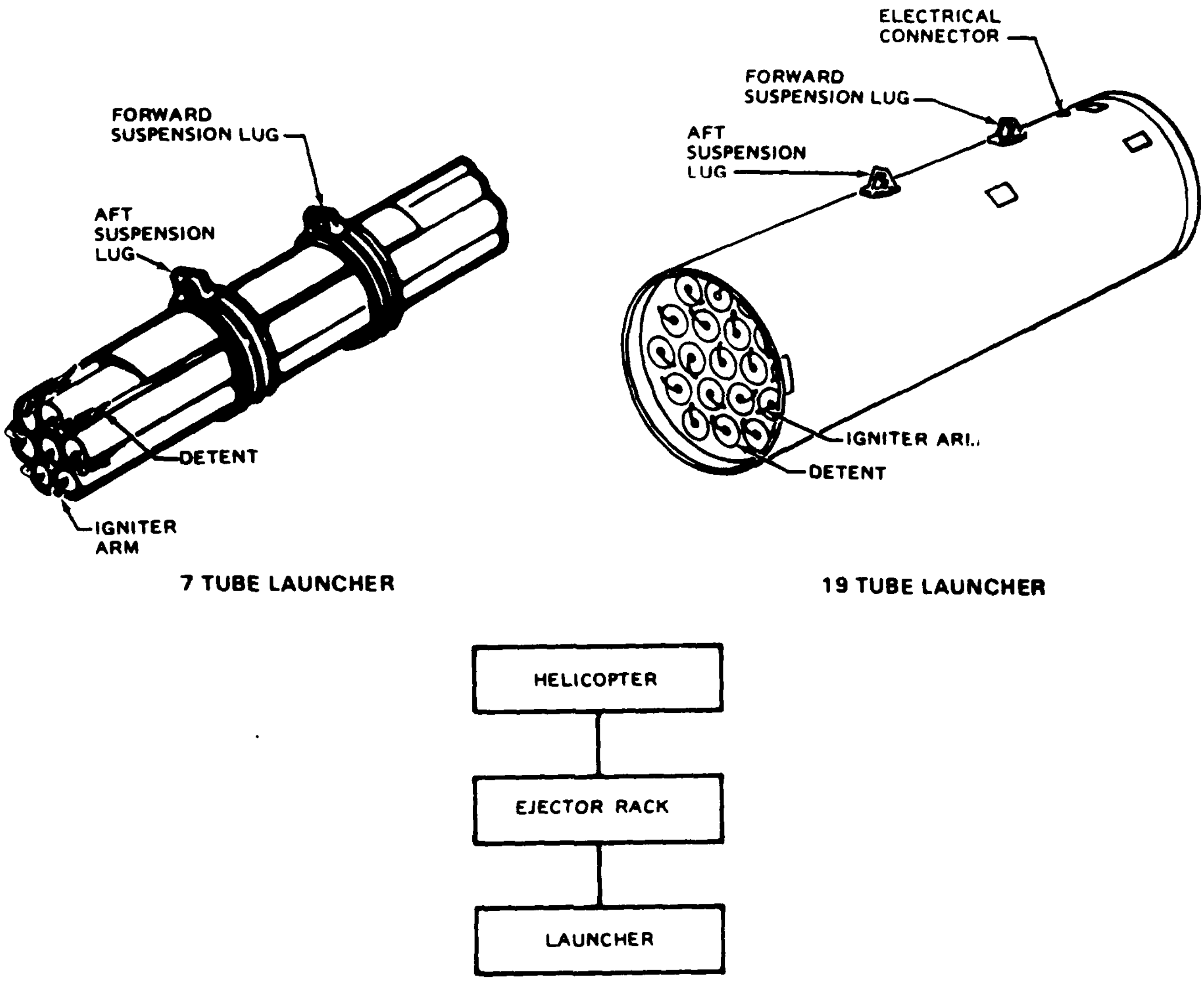


Figure 6. Folding fin aerial rocket (2.75-inch) launcher.

Each of the armament subsystems are interfaced with each other and require the following subsystems be fully functional in order to have a fully functional armament system:

a. Telescopic sight unit

b. Helmet sight subsystem

c. Universal turret subsystem

d. Rocket management subsystem

e. TOW missile subsystem

f. Air data subsystem

g. Laser range finder

h. Heads-up display system

i. Collective transducer

j. Airborne laser tracker

k. Attitude reference gyro

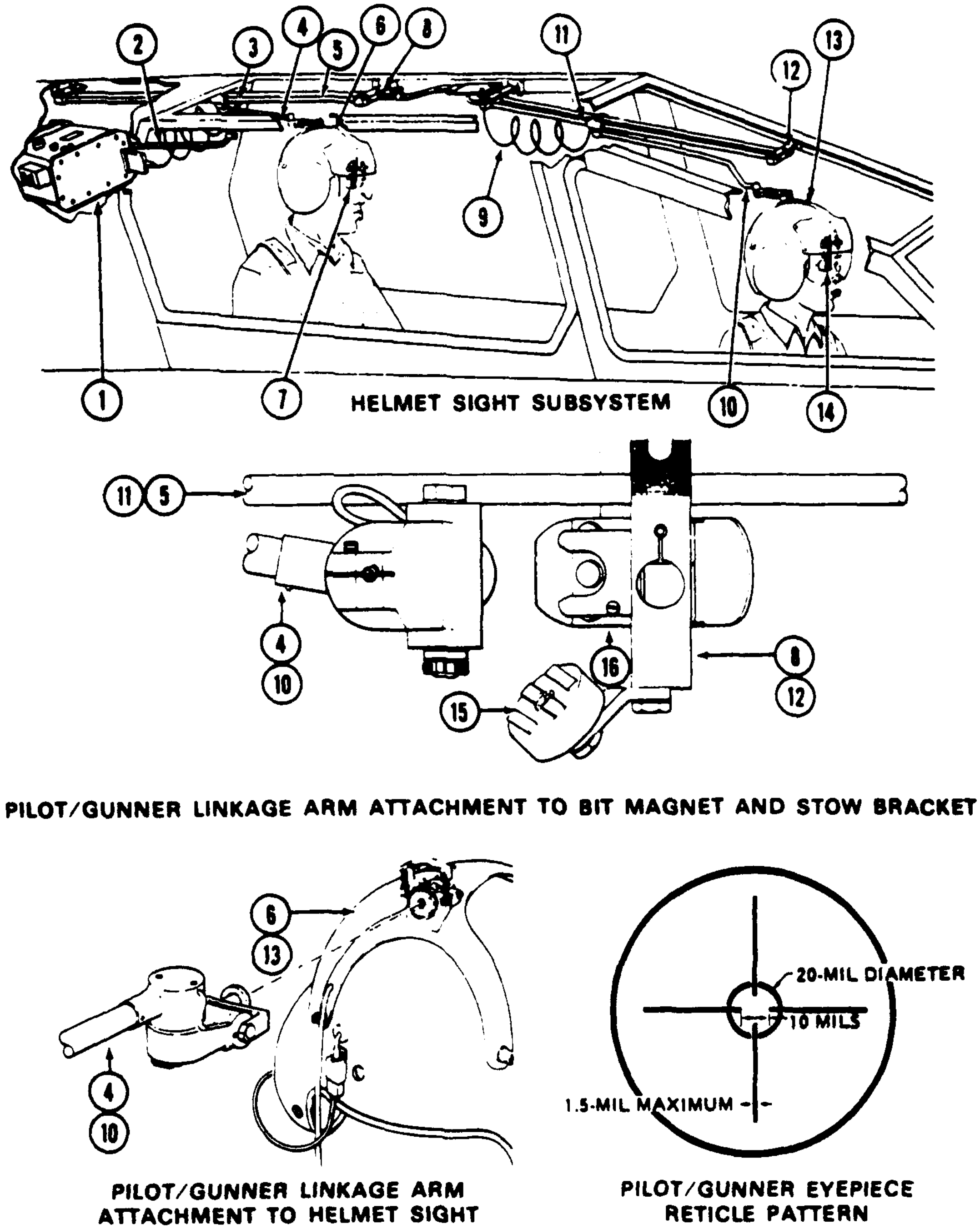
l. Magnetic compass set

m. Radar altimeter

n. Torquemeter

o. Doppler navigation system

The pilots are able rapidly to acquire targets and direct the turret and/or the telescopic sight unit through the use of a helmet sight subsystem. Data from the telescopic sight unit, the helmet sight subsystem, the various armament subsystems, and the subsystems monitoring the aircraft and the wind direction and velocity are fed into the fire control computer. Here, the solutions are derived and sent to the heads-up display system for rocket fire control. A depiction of the helmet sight subsystem (HSS) is shown as Figure 7. While not as sophisticated as the integrated helmet and display sighting system (IHADSS) in the AH-64 system, the HSS has proven to be quite capable of directing fire and destroying enemy targets as was seen in the Vietnam conflict. Some limitations readily can be seen in the picture in the interface witn the rail system overhead and the reticles which make the mounting of night vision devices very difficult.



1. Electronic interface assembly
2. Gunner extension cable
3. Pilot linkage cable
4. Pilot linkage arm
5. Pilot linkage rails
6. Pilot helmet sight
7. Pilot eyepiece
8. Pilot linkage front support
9. Gunner linkage cable
10. Gunner linkage arm
11. Gunner linkage rails
12. Gunner linkage front support
13. Gunner helmet sight
14. Gunner eyepiece
15. BIT magnet
16. Stow bracket

Figure 7. Helmet sight subsystem (HSS).

Description of the simulation system

The AH-1S FWS is a motion-based device designed for training aviators in the use of AH-1S modernized Cobra helicopters (TM 55-6930-216-10). The device consists of two simulator compartments, one containing a cockpit for the pilot and the other containing a cockpit for the gunner (Figure 8 and 8a). Each compartment houses a position for the instructor operator (IO) station and an observer station. A six-degree-of-freedom hydraulic motion system is an integral part of each cockpit. The simulator is equipped with a visual system that simulates the natural environmental surroundings. A central computer system controls the operation of the simulator complex. The simulator is used to provide transition training, proficiency training, and weapons delivery practice. The simulator also is used in the training of aircraft control, cockpit preflight procedures, all normal and emergency flight maneuvers, instrument flight operations, visual flight operations, night vision goggles (NVG) training, as well as those tactical skills necessary to conduct nap-of-the-earth (NOE) flight, low-level flight, and contour flight. A partial listing of training tasks that can be performed in the simulator is shown in Table 1. The simulator is capable of full mission simulation while training each pilot independently or both pilots simultaneously.

The simulator compartment houses the cockpit station and the IO station (Figure 9). The pilot's station is located in the forward area of each compartment. Within the cockpit are all the controls, indicators, and panels located in the aircraft. Controls which are not functional are physically present to preserve the appearance of a 100 percent configuration. Loudspeakers are located in the simulator compartment to simulate aural cues. Aural cue sounds can be regulated in loudness by the instructor/operator.

Each of the pilot's seats are vibrated individually to simulate both continuous and periodic oscillations and vibrations experienced by the crew during normal and emergency flight conditions and maneuvers. However, these vibrations are isolated from the IO and observer stations by the use of damping elements in the seat mounting construction.

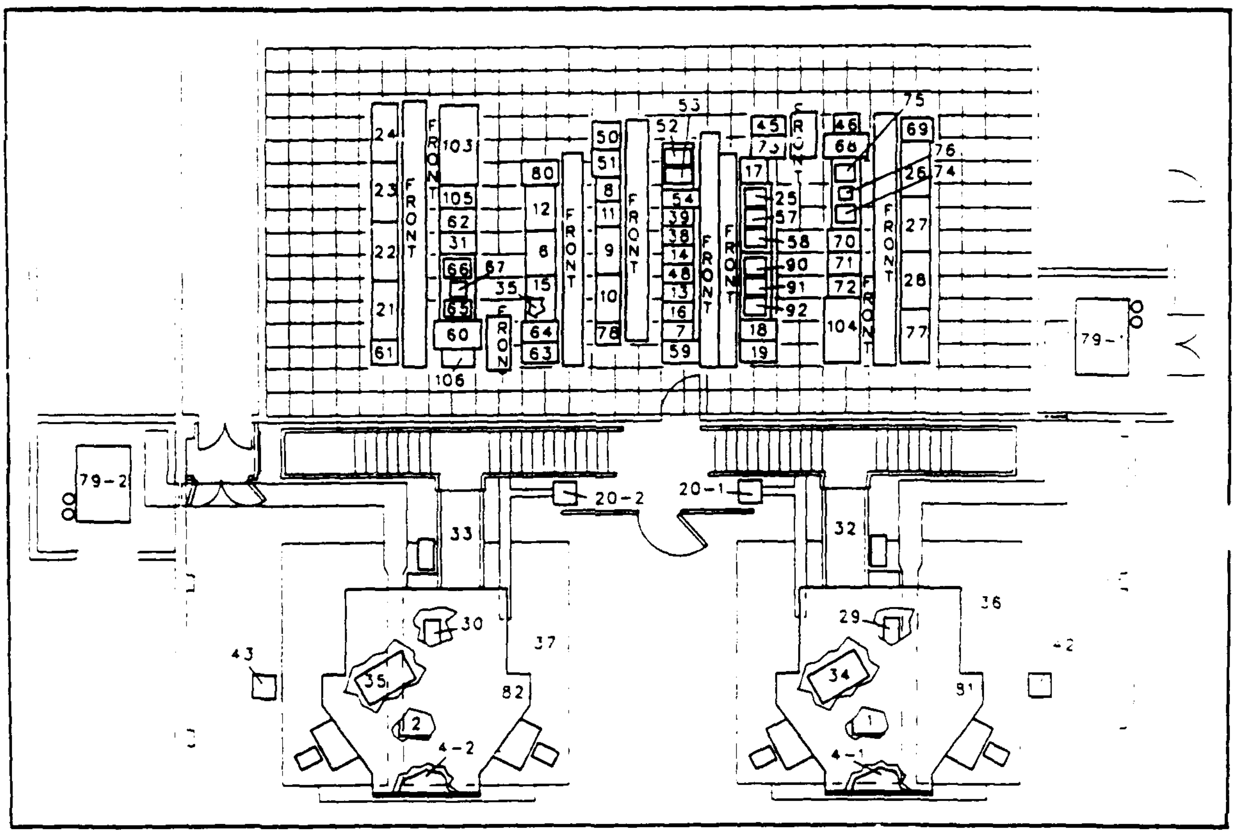


Figure 8. Typical simulator and computer rooms of system complex.

REF DES	DESCRIPTION
1	COCKPIT
2	COCKPIT CABINET
3	PERIPHERAL CABINET
4	MOTION PLATFORM
5	AIR CONDITIONER
6	CENTRAL PROCESSOR UNIT (CPU)
7	AUXILIARY PROCESSOR UNIT NO. 1 (APU-1)
8	AUXILIARY PROCESSOR UNIT NO. 2 (APU-1)
9	MAGNETIC TAPE UNIT (MTU)
10	(NOT USED)
11	POWER DISTRIBUTION CABINET
12	DISC NO. 1 (DISC-1)
13	DISC NO. 2 (DISC-2)
14	VISUAL DISPLAY UNIT NO. 1 (VDU-1)
15	VISUAL DISPLAY UNIT NO. 2 (VDU-2)
16	VISUAL DISPLAY UNIT NO. 3 (VDU-3)
17	PRINTER/PLOTTER
18	THERMAL PRINTER
19	(NOT USED)
20	MOTION CABINET
21	(NOT USED)
22	(NOT USED)
23	HYDRAULIC PUMPING UNIT
24	400-HZ MOTOR-GENERATOR
25	400-HZ CONTROL PANEL
26 THRU 28	(NOT USED)
29	INTERCOM - BRIEFING ROOM (NOT SHOWN)
30	BOARDING RAMP
31	EXTENSION LIGHT ASSEMBLY
32 THRU 37	(NOT USED)
38	DIG CENTRAL PROCESSOR UNIT (CPU)
39	DIG CPU I/O EXPANSION UNIT
40	DIG MAGNETIC TAPE UNIT (MTU)
41	DIG CRT TERMINAL
42	DIG HARDCOPY UNIT
43	DIG CRT TERMINAL
44	DIG DISC
45	DIG DISC
46	DIG LINE PRINTER
47	DIG VISUAL CONSOLE
48	DIG SCANLINE COMPUTER CABINET
49	DIG VIDEO GENERATOR CABINET
50	DIG FRAME CALCULATOR CABINET
51	DIG PRIORITY AND SECTOR PROCESSOR (PSP) UNIT
52	DIG POWER CONTROL UNIT
53	DIG TEXTURE CABINET
54 THRU 79	(NOT USED)
80	VISUAL INTERFACE CABINET
81	VISUAL DISPLAY INSTALLATION

Figure 8 (continued). Typical simulator and computer rooms of system complex.

Table 1.

Maneuvers performed in the simulator

Basic maneuvers	Emergency maneuvers
Cockpit procedures	Forced landings (normal and high-speed)
Normal approach to hover	Autorotative glides and turns
Startup and hover	Simulated tail rotor control failure
Normal approach to ground	Simulated hydraulic failure
Hovering flight	Emergency procedures (including emergency shutdown)
Straight and level flight	Autorotations with turns (power recovery, termination with power, touchdown)
Traffic pattern	Hovering autorotation
Level turns	Basic autorotations
Takeoff from hover	Low-level, flat-glide autorotation
Straight climb and turn	Low-level, high-speed autorotation (power recovery, termination with power, touchdown)
Takeoff from ground	
Turning climbs/descents	

Advanced maneuvers	Gunnery maneuvers
Max performance takeoff	Weapons cockpit procedures
High-speed dive (normal)	Combat sight setting
Steep approach	Diving fire
High-speed dive (steep)	Running fire
Running landing	Diving to running fire
Running takeoff	Low-level/NOE firing
Basic autorotation	Low-level/NOE firing (combat sight setting
Night operations	
High-speed flight	
Decelerations	
Stability and control augmentation (SCAS) "off" flight	

Nap-of-the-earth maneuvers
Low-level navigation
NOE downwind approach
Hovering in/out of ground
NOE navigation effect
NOE takeoff
NOE radio procedure
NOE flight
NOE deceleration
NOE approach
Masking and unmasking
NOE downwind takeoff techniques
NOE downwind flight
Scan and detection techniques

<u>Note</u>: NOE - Nap-of-the-earth

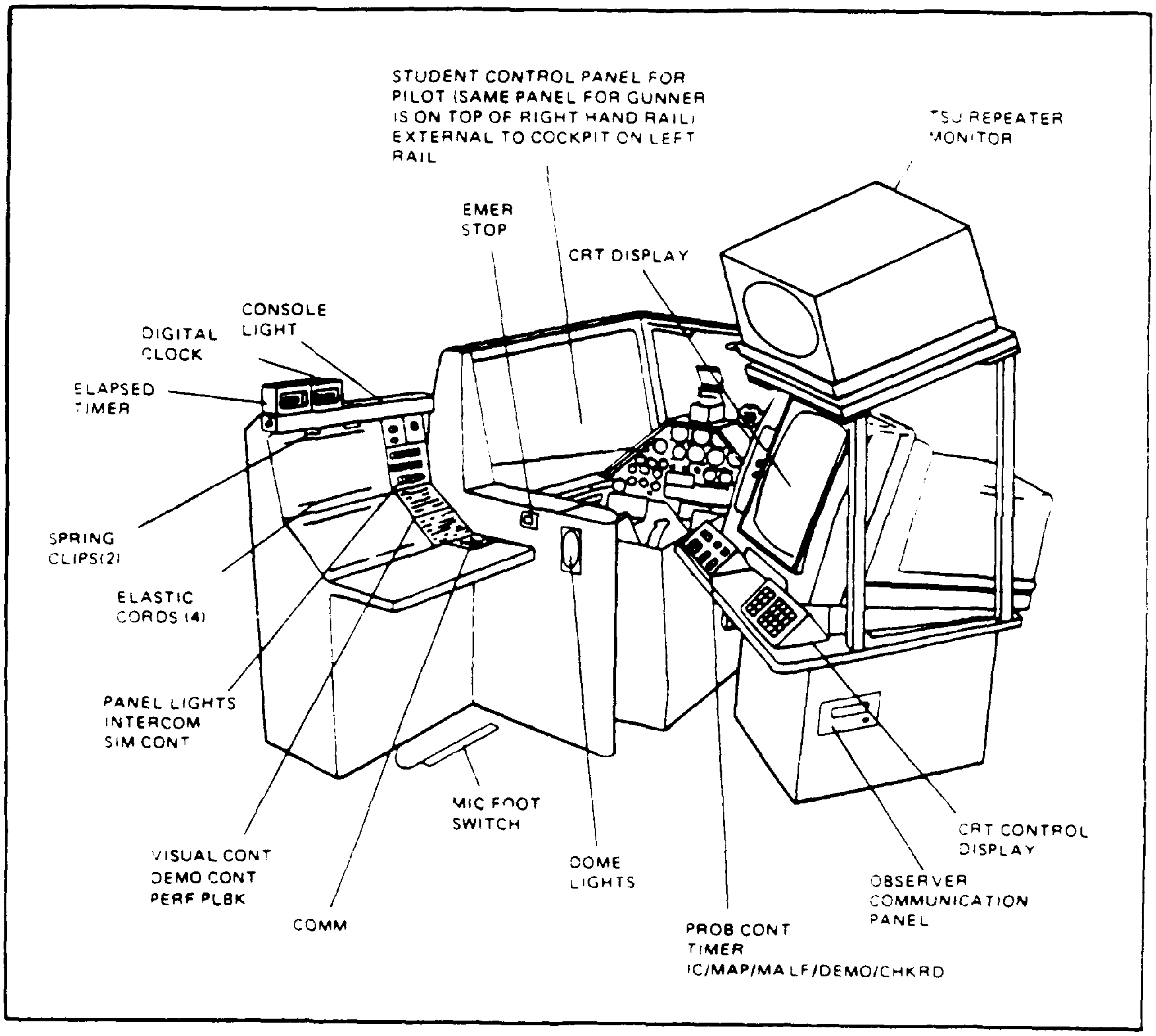


Figure 9. Instructor/operator station general layout.

Cooling of each compartment is provided by a single air conditioner outside the compartment enclosure on the simulator room floor. A thermostat mounted on the bulkhead in the aft portion of the compartment controls the temperature setting in the cockpit. The air is ducted through the compartment area and the normal helicopter heating and defrosting ducts. The AH-1S is equipped with an environmental control system, however, the switches and controls in the simulator are nonfunctional.

The simulator compartment is mounted on a 60-inch six-degree-of-freedom motion system consisting of a moving platform assembly driven and supported from below by six identical hydraulic actuators. The motion system provides pitch, roll, and yaw, lateral, longitudinal, and vertical movement, as well as a combinations of all. Motion of the simulator compartment can be controlled to simulate motion due to pilot inputs, those resulting from rotor operation, rough air, and wind, changes in aircraft center of gravity due to fuel expenditure or weapon and ammunition depletion, as well as emergency conditions and system malfunctions. All motions except pitch are imperceptibly washed out to the neutral position after the computed accelerations have reached zero. Pitch attitude is maintained as necessary to simulate sustained longitudinal acceleration cues.

The motion system simulates the complex and repeated cues occurring during all the maneuvers associated with the airwork. When used by the instructor-operator, turbulence is superimposed on the maneuver being performed with the appropriate effect on yaw and roll, climb and descent, and variations in airspeed. The motion system superimposes all normal periodic oscillations of the aircraft, lateral instability, and aircraft vibration up to 5 cycles per second. The electrohydraulic seat shaker is used to simulate continuous higher frequency vibrations in lieu of the motion system. The following values are given as the maximum platform excursion values given from a reference point when the motion platform is at a neutral position:

Vertical	33 inches up, 38 inches down
Lateral	±58 inches
Longitudinal	±53 inches
Pitch	31 degrees down, 36 degrees up
Roll	±32 degrees
Yaw	±32 degrees

Motion can be frozen at any instant and the simulator has the ability to enter a crash override mode where motion can continue despite impact with the ground or other obstacles.

The pilot and gunner stations are provided with forward, left, and right side window displays (Figure 10). The TSU is a separate computer graphic visual display system. The visual generation system consists of several functional areas. The first is the wide-angle-collimating (WAC) which presents the video image to the crew through the left, center, and right displays. The two digital image generators (DIG) are full color visual displays that provide imagery for day, night, and dusk scenes as well as replicating the effects of the searchlight/

landing light on the visual displays. The next is the TSU symbol generator with a display in the gunner cockpit. Also, there is a full-color repeater display in the gunner instructor/operator station.

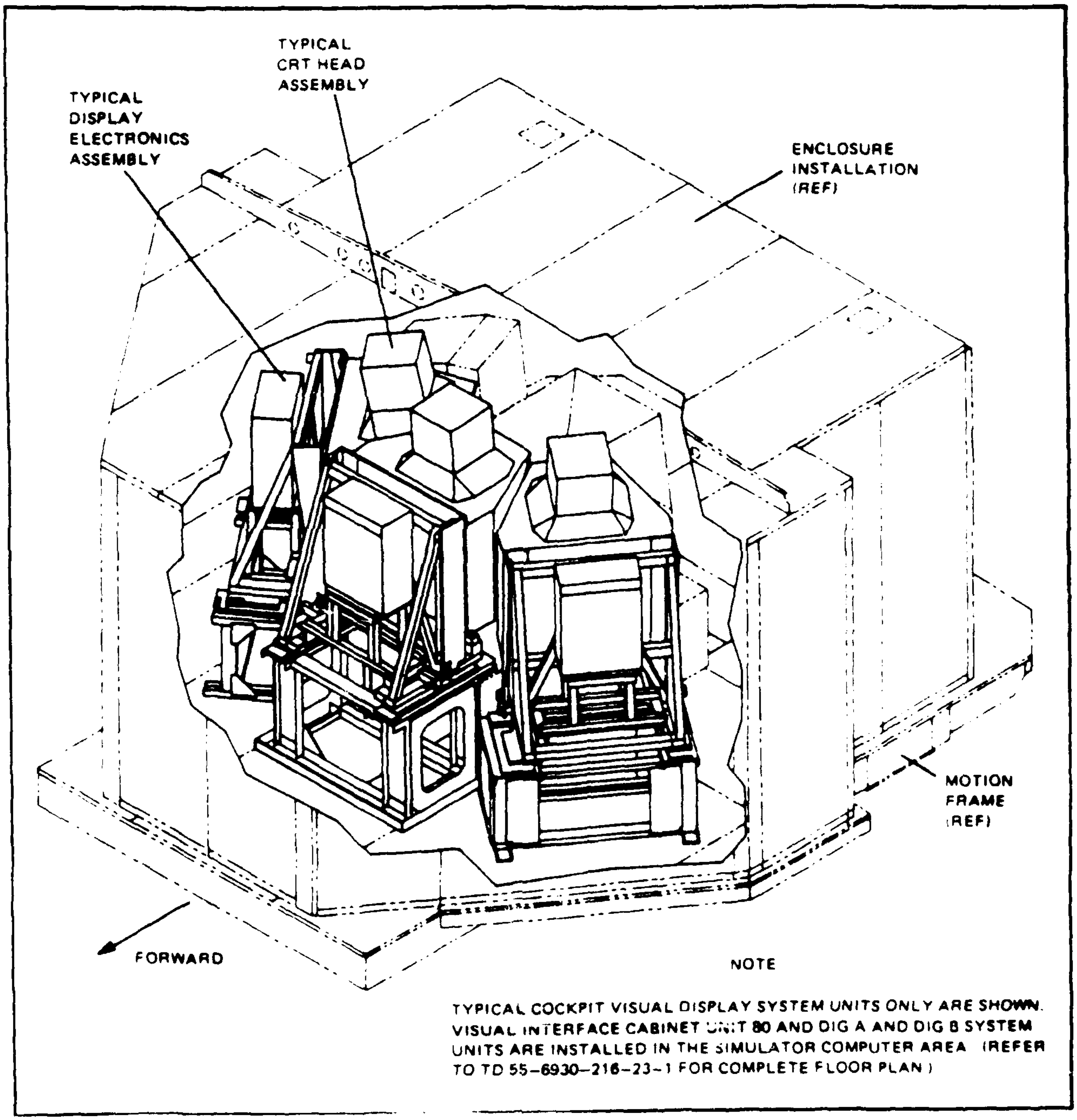


Figure 10. Typical visual display system installation.

The database is a generic European scene of an area 32-by-40 kilometers. Navigation and communication radio capabilities include 126 navigation aids. The aircraft has any 1 of 10 different weapons loading configurations. The computer can designate 10 different targets for engagement from a selection of 16 targets in the memory. One of the targets can be a moving target. The simulator will replicate gun tracer trajectories, folding-fin aerial rockets (FFAR), and TOW missile flightpaths, weapon burnout, and ground impacts.

The displays are either full color or monochromatic. The monochromatic scene display is designed specifically to be compatible with the use of NVGs. During selection of this mode, the leadship lights are blanked and an exhaust trail is generated from the leadship. The simulator does not input directly to the NVG except for the out-the-window imagery. Cockpit lighting is compatible with the AN/AVS-6 aviator night vision imagery system and the AN/PVS-5 NVGs. Blue-green lighting is provided by floodlights and utility lights.

The computer system consists of five Digital Equipment Corporation PDP-11/55 computer systems with associated memory and peripheral units. There are two software programs for the operational environment, the executive program, and the real-time simulation program. Real-time programs, in conjunction with the appropriate hardware, provide simulation of flight performance, engine and related systems, aircraft accessory systems, radio communication and navigation equipment, atmospheric conditions, flight control systems, malfunctions and threat.

The collimating optics used in this simulator are shown in Figure 11. The alignment of the optics in this system produces parallel light rays giving the appearance that the image is at optical infinity. As shown in the diagram at Figure 12, our eyes provide distance measuring information to the brain based partly on the angle between the eyes, or ocular convergence. As objects move closer to the viewer, the eyes must converge in order for both eyes to remain focused on the object. As the object moves further away, the angle increases giving the brain data on the distance. Beyond a point approximately 50 feet away from the viewer, the eyes point in virtually parallel directions.

In the visual system of the simulator, a spherical mirror is used to effect the collimation of the light rays. When the point source of light is placed at a distance equal to one-half the radius of the mirror, rays will enter the mirror and reflect in parallel. Therefore, when the viewer looks at the reflected image it has the illusion of being quite far away.

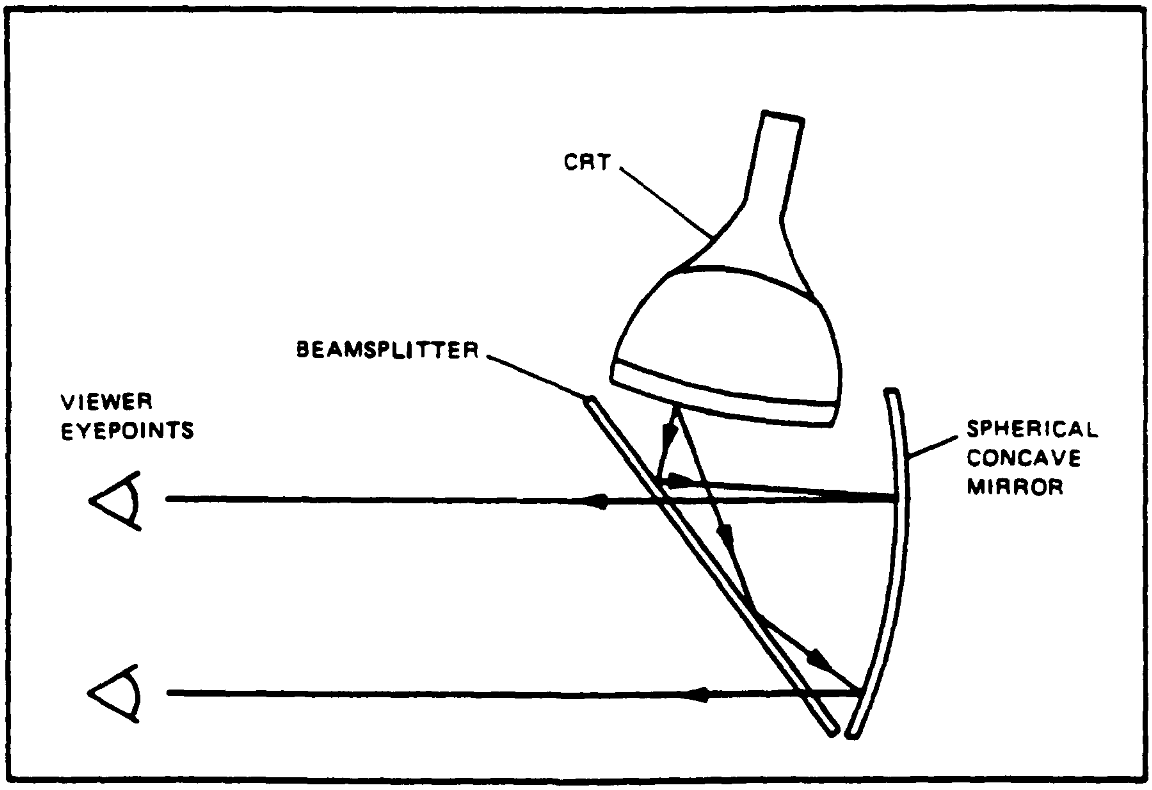


Figure 11. Collimating optics representation.

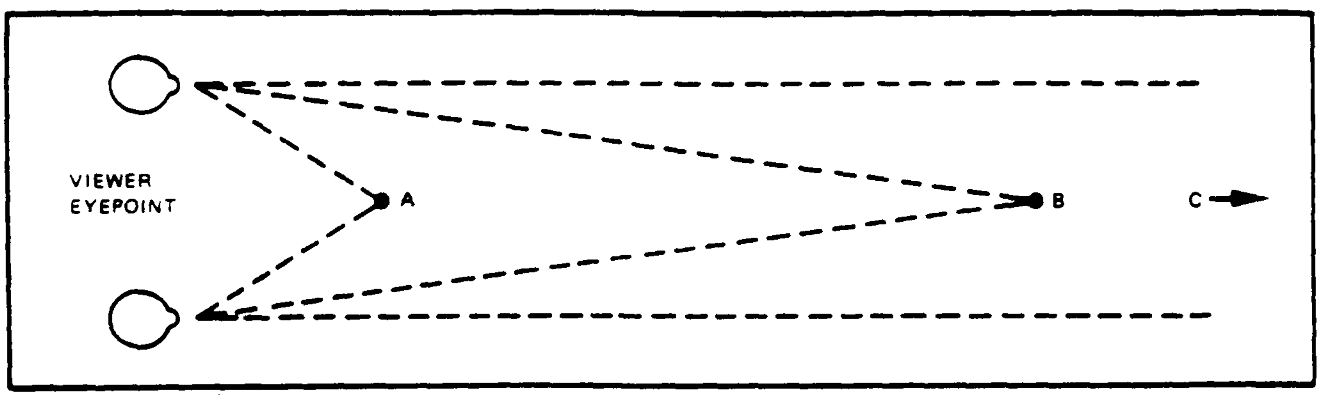


Figure 12. Ocular convergence representation.

There are three main components of the collimating optics in this simulator: the CRT, the spherical concave mirror, and a beamsplitter (TM 55-6930-216-23-6). The beamsplitter is necessary to ensure the CRT is out of the line of sight of the pilot. The beamsplitter is partially reflective and allows only 50 percent of the light to pass through, the rest is reflected to the mirror. After reflecting off the mirror, the light rays exit through the beamsplitter and again lose intensity and are viewed by the pilot. As a result, the CRT is driven to near its maximum brightness capabilities to compensate for the resulting 80 (approximate) percent loss of light.

As shown in Figure 13, at any given point on the CRT, the distance from the CRT to the beamsplitter to the mirror is one half the mirror's radius. At the design eyepoint, the rays of light are virtually parallel. Figure 14 shows the critical dimensions of the visual system.

The TSU display system consists of a color monitor and the TSU symbol generator. Using the video signal from the symbol mixer in the TSU symbol generator as input, the TSU display provides a full-color visual scene to the gunner as well as the symbology. The TSU provides an apparent field of view of 36-degree circle diameter, with a resolution of 7 arc-minutes per optical line pair.

The simulator can operate in three modes of training: Training, checkride, and demonstration. In the training mode, the flight is under the control of the instructor-operator who can use numerous capabilities of the simulator to effect the training required. These capabilities include automatic performance recording, automatic demonstrations, numerous malfunctions, as well as other automatic or semiautomatic instructor aids.

In the checkride mode, automatic performance recording and error scoring programs are employed using an instructor-generated program. The instructor preprograms aircraft flight conditions of visual, instrument, tactical visual, and tactical instrument exercises, which are displayed to the crew. Once initiated, the program progresses without interruption or until the crew is unable to continue due to crashing or becoming lost and way off-course.

In the demonstration mode, the simulator is used to playback any of 20 recorded demonstrations. This includes recording and storing the particular flight in memory, adding commentary, and synchronizing the two in order to effect the demonstration. Each demonstration is limited to approximately 30 minutes due to the audio being limited to that amount. There is sufficient disk space, however, to record 210 minutes of dynamic profile. During this playback of the demonstration, the primary flight controls are positioned and driven by the computer. Switch activation is simulated, but the switch position is not physically or automatically moved.

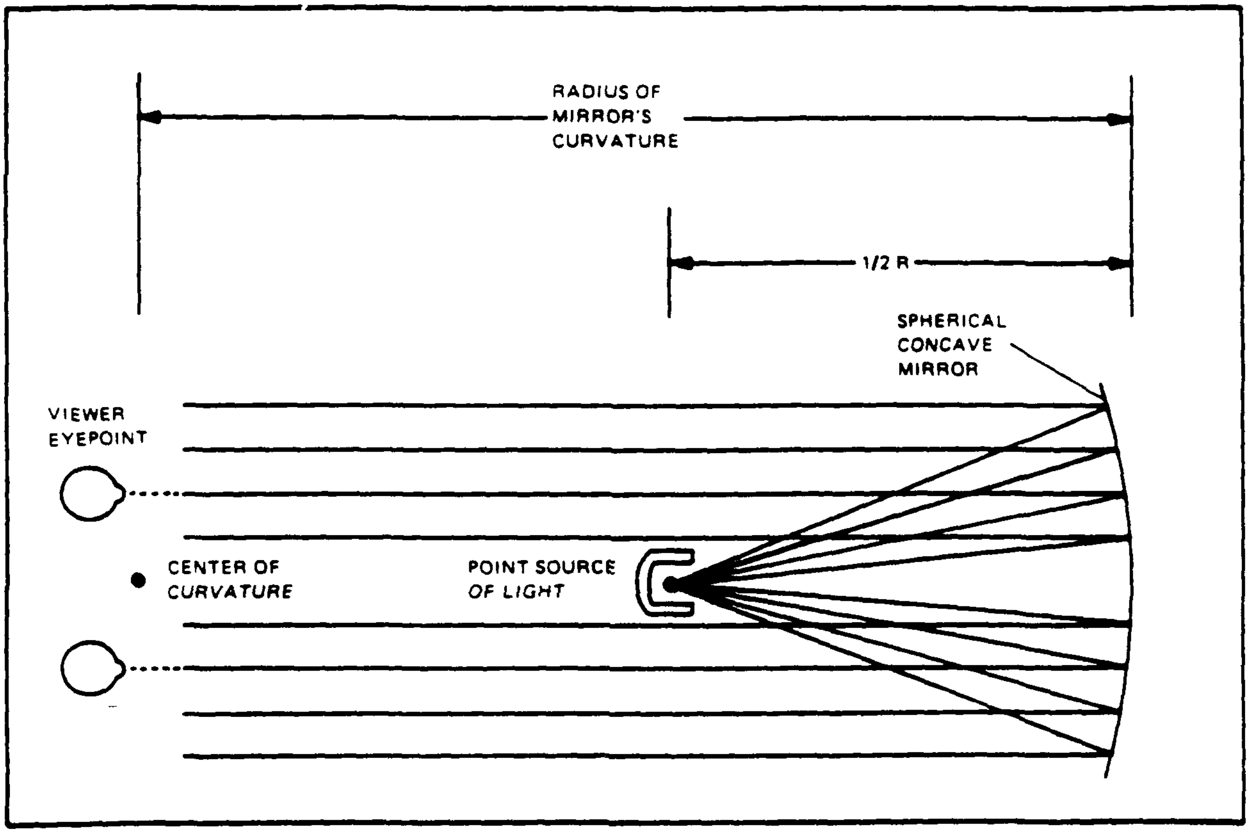
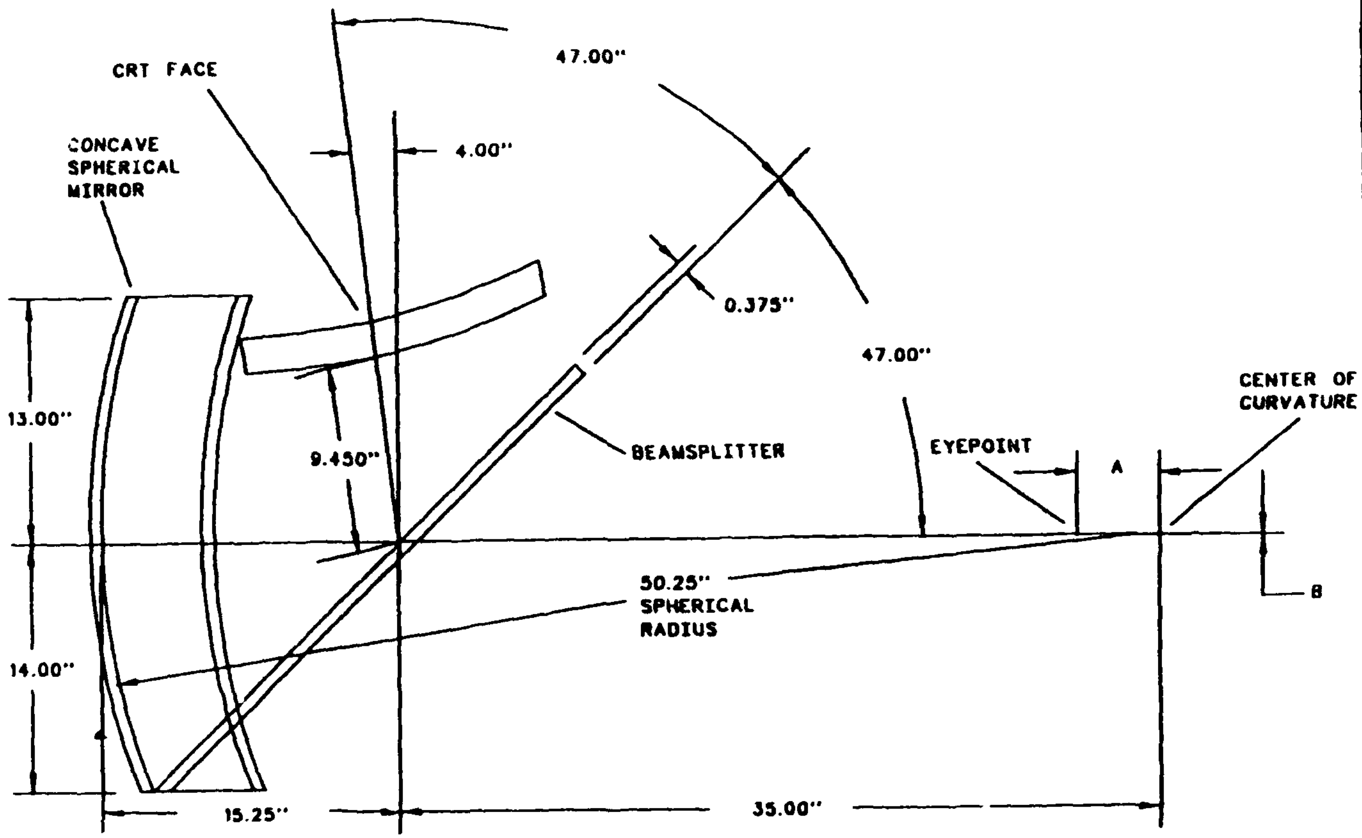


Figure 13. Basic collimation concept.



	DIMENSION	
WINDOW	A	B
RIGHT	4.10	-
CENTER	4.10	0.17
LEFT	4.10	-

NOTE

MIRROR AND BEAMSPLITTER DIMENSIONS ARE FOR REFERENCE ONLY.

Figure 14. Mirror/beamsplitter optical diagram.

The simulator can operate in either the independent or integrated mode during these training modes of operation. In the independent mode, each cockpit can be flown on different routes and with different scenarios programmed. This allows each pilot to be training on a different set of malfunctions, initial conditions, weapon loading configurations, and selection of navigation and communication equipment and facilities.

In the integrated mode, the flight is under the positive control of the pilot instructor operator. The cockpits experience the same conditions throughout the flight as though they were in the same airframe. In this mode, there really is no need for a gunner instructor except as an observer. All aspects of the training can be accomplished without the gunner instructor present.

Method

This field study was designed to assess incidence of simulator sickness in visually coupled Army flight simulators. The survey measures were chosen to be comparable to those utilized in U.S. Navy and U.S. Coast Guard surveys. This way, data obtained would complement and expand the Navy's database of 10 simulators (Kennedy et al., 1987b, Van Hoy et al., 1987), the Coast Guard data (Ungs, 1987), and previous Army research conducted in the Apache combat mission simulator (Gower et al., 1987). As employed in previous surveys, this study consisted of an onsite survey of pilots and IOs using a motion history questionnaire (MHQ), a motion sickness questionnaire (MSQ), and a postural equilibrium test (PET) (Appendix A).

Aviators

The 74 Army aviators surveyed ranged in age from 19 to 43 (mean 28.8, SD 6.43). Their ranks ranged from warrant officer 1 (WO1) to chief warrant officer 4 (CW4), and first lieutenant (1LT) to lieutenant colonel (LTC). Rotary-winged flight experience was in the range 1 to 6000 flight hours (mean 1135.03, SD 1254.56). Total simulator flight hours was in the range of 0 to 1000 (mean 80.05, SD 148.35).

Measures

The MHQ, originally developed by Kennedy and Graybiel (1965), is a self-report form designed to evaluate the subject's past experience with different modes of motion and the subject's reported history of susceptibility to motion sickness. The MHQ is administered once and was scored according to procedures described in Lenel et al. (1987).

The MSQ is designed to assess the symptomatology experienced as a result of training in the simulator. The MSQ is divided into four sections. The first section obtains preflight background information to place subjects in the proper category according to flight position, duties, total flight time in the aircraft and in the simulator, and history of recent flight time in both the aircraft and the simulator.

The second section is the preflight physiological status section. This section is administered at the simulator site, and gathers benchmark data as to the subject's recent exposure to prescription medications, illness, use of alcohol and/or tobacco products, and amount of sleep the previous night.

The third section is the simulator sickness questionnaire (SSQ) (Lane and Kennedy, 1988). The SSQ is a self-report form consisting of 28 symptoms that are rated by the participant as either being present or absent or in terms of degree of severity on a 4-point Likert-type scale. A diagnostic scoring technique is applied to the checklist resulting in scores on three subscales--nausea, visuomotor, and disorientation--in addition to a total severity score.

Scores on the nausea (N) subscale are based on the report of symptoms which relate to gastrointestinal distress such as nausea, stomach awareness, salivation, and burping. Scores on the visuomotor (V) subscale reflect the report of eyestrain-related symptoms such as eyestrain, difficulty focusing, blurred vision, and headache, while those on the disorientation (D) subscale are related to vestibular disturbances such as dizziness and vertigo. Scores on the total severity (TS) scale are an indication of overall discomfort.

For all scales, a score of 100 indicates absence of sickness. The average scores for all simulators in the NTSC database are 107.7, 110.6, 106.4, and 109.8 on the N, V, D, and TS scales, respectively. The SSQ is administered prior to the flight and then immediately after the simulator flight, and provides data regarding any increase or decrease in severity of the symptoms that the subject is experiencing.

If the subject was experiencing an increase in any of the symptoms, an attempt was made to conduct a structured interview with him in order to provide some information regarding recovery from the experienced symptoms. A new question added to the postflight SSQ asked the pilots about the symptoms experienced in the simulator and whether or not they were the same as or worse than the same symptoms experienced in the aircraft conducting the same maneuvers.

The fourth section is the postflight information section which provides data on the flight conditions the pilot experienced while in the simulator and information concerning the status of the various systems within the simulator.

Postural equilibrium tests (Thomley, Kennedy, and Bittner, 1986) were administered concurrently with the MHQ and MSQ. These tests consist of three subtests, each designed to measure an aspect of postural equilibrium, as follows:

a. Walk-on-floor-with-eyes-closed (WOFEC). The subject is instructed to walk 12 heel-to-toe steps with his eyes closed and arms folded across his chest. The subject is given a score (0-12) based on the number of steps he is able to complete without sidestepping or falling. The subject is tested five times, both pre- and postflight. Subjects are scored on the average number of steps taken using the best three of the five tests.

b. Standing-on-preferred-leg-with-eyes-closed (SOPLEC). The subject designates his preferred leg (the leg he would use to kick a football) and this is annotated on the form. The subject then is asked to stand on his preferred leg for 30 seconds with his eyes closed and arms folded across his chest. The experimenter records the number of seconds the subject is able to stand without losing balance or tilting to greater than a 5 degree list from the vertical. The subject is scored on the number of seconds he is able to stand. The test is administered five times with the best three of the five being used for analysis.

c. Standing-on-nonpreferred-leg-with-eyes-closed (SONLEC). The SONLEC is administered and scored in the same manner as the SOPLEC. The SONLEC will use the opposite leg from the SOPLEC and is administered five times. The subject's score is the average number of seconds he is able to stand, using the best three of the five tests for the analysis.

Procedure

In order to gather the most comprehensive data in the least intrusive manner, the surveys were administered to all aviators who presented themselves at the simulator site for flight periods. No attempt was made to randomize the population, but rather to study the problem in the operational setting in which it is found and using flight scenarios normally found during training.

The site used was Fort Rucker, Alabama. A target sample size of 100 was the objective, but due to time constraints and the nuances of operational usage of the simulator, only 85 observations were obtained from 74 subjects. They performed the normal program of instruction as prescribed in the AH-1S aircraft qualification course, one of several operations orders (OPORD) designed to maintain proficiency, or other aircrew training manual (ATM) tasks necessary to maintain their proficiency. The investigator did not perform any intervention or exercise any control over the flights in the conduct of this survey. All aviators scheduled for flight were surveyed. Each was guaranteed anonymity and each was permitted nonparticipation. Data obtained from the questionnaires and the PET were entered into a generic database using the programs in use at the NTSC, and data reduction and analyses were performed as in previous studies. The data in this report now are incorporated into the Navy's simulator sickness database, which also includes Coast Guard data in order to determine commonality of symptoms and simulator usage and design (Gower et al., 1987).

Results

Symptomatology

Table 2 shows the number of pilots reporting key postflight symptomatology. To counter the possible inflationary effects of preflight symptomatology reported on postflight symptomatology, percentages for each particular symptom are based only on the pilots who did not report the symptom prior to training. This procedure is likely to underestimate the severity of the problem in that pilots who reported a symptom prior to the flight that was worse after the flight are not included. Symptoms have been categorized into those traditionally associated with motion sickness versus those which are associated with asthenopia (eyestrain).

Eyestrain was the most commonly reported asthenopic symptom, followed by headache. An eyestrain component is present to some degree in other forms of motion sickness (Lane and Kennedy, 1988), but is a prominent facet of simulator sickness implicating visual and visual vestibular interactions as causal mechanisms. Improper calibration of virtual image displays may lead to excessive accommodation and vergence demands (i.e., beyond optical infinity), unequal accommodative demands between the two eyes, and conflicts between accommodation and vergence systems (Ebenholtz, 1988), all of which may produce asthenopia. It should be noted that symptoms associated with asthenopia per se include vertigo, indigestion, nausea, and vomiting (Ebenholtz,

1988) and, thus, may be similar to motion sickness in terms of cause (Morrissey and Bittner, 1986).

Table 2.

Percentage* (frequencies) of aircrew reporting postflight symptomatology in the AH-1S FWS simulator (85 total possible cases).

Asthenopia	Percentage	Motion sickness	Percentage
Eyestrain	36.5 (27/74)	Fatigue	27.2 (15/55)
Blurred vision	2.4 (2/85)	Sweating	20.6 (15/73)
Difficulty focusing	8.7 (7/81)	Nausea	13.2 (11/83)
Difficulty concentrating	5.1 (4/78)	Dizziness (eyes closed)	4.7 (4/85)
Headache	14.1 (11/78)	Dizziness (eyes open)	2.4 (2/85)
		Vertigo	1.2 (1/85)
		Salivation increase	3.7 (3/81)
		Stomach awareness	9.8 (8/82)
		Fullness of the head	3.8 (3/78)

* Percentages for each symptom are based on aircrew who did not report the symptom prior to training

Fatigue and sweating were most commonly reported symptoms associated with motion sickness followed by reports of nausea and stomach awareness. This is consistent with previous surveys of simulator sickness (Gower et al., 1987); Kennedy et al., 1987b).

In Table 3, information shown in Table 2 has been presented along with comparable data available for other helicopter simulators. Incidence of eyestrain in the AH-1S simulator is as high as that reported in the 2F64C (SH-60) simulator, the Navy's simulator associated with the highest incidence of simulator sickness. Moreover, incidence of headache, difficulty focusing, nausea, and stomach awareness in the AH-1S simulator is among the three highest in the sample of helicopter simulators suggesting that severity of simulator sickness experienced by pilots training in the AH-1S is worse than average.

Table 3.

Percentage* of aircrews reporting key symptomatology in seven helicopter simulators

	Army		Navy				
Simulator:	2B33	2B40	2B42	SH3H	CH46E	CH53D	CH53E
Aircraft:	AH-1	AH-64	TH-57C	2F64C	2F117	2F121	2F120
Asthenopia							
Eyestrain	37	24	27	37	16	21	23
Difficulty focus	9	9	7	24	6	6	10
Headache	14	14	7	31	12	9	17
Motion Sickness							
Nausea	13	6	5	15	9	8	11
Dizzy, eyes open	2	1	4	9	3	1	6
Stomach awareness	10	5	1	14	7	2	4
Vertigo	1	1	3	10	3	1	4
Observations:	85	434	111	223	281	159	230

* Data sources--Army 2B40: Gower et al. (1987); Navy 2B42: Fowlkes et al., 1989; Navy 2F64C, 2F117, 2F121, and 2F120: Kennedy et al., 1987b.

The simulator sickness questionnaire (SSQ) scoring technique (Lane and Kennedy, 1988) was applied to the pre- and postflight symptom checklist. Descriptive statistics and paired measures t-test values for these data are shown in Table 4. These data show that aviators who train in the AH-1 simulator experience a marked change in symptomatology over the course of a training session.

A separate analysis revealed that scores on the disorientation subscale were lower for aircrews who flew longer flights (>1.5 hours). In contrast, visuomotor scores were higher for aircrews who flew longer hops while, essentially, there was no difference on the nausea subscale. It is possible that disorientation is a component of simulator sickness in the AH-1S simulator that, while initially strong, may quickly adapt out.

Table 4.

Pre- and post-SSQ means (standard deviations) and paired t-tests.

(85 observations)

Scale	Pre	Post	Difference Mean	*t*	*p*
Nausea	104.7 (8.9)	110.9 (17.6)	6.17	3.18	.002
Visuomotor	107.3 (12.3)	114.0 (16.1)	6.69	4.75	.000
Disorientation	102.1 (5.5)	106.4 (1[illegible])	4.26	2.82	.006
Total severity	106.0 (9.8)	112.9 (16.6)	6.86	4.08	.000

Figures 15 through 18 show the severity of postflight SSQ scores along with data available for other flight simulators (both fixed- and rotary-wing). Following Lane and Kennedy's (1988) suggestion for examining postflight data, only AH-1S aircrews who reported that they were in their usual state of fitness were included in the calculation of postflight SSQ scores presented in Figures 15 through 18. It can be seen the severity of postflight symptomatology on each of the SSQ scales for the AH-1S simulator is among the highest in the sample, substantiating the data for individual symptoms shown in Tables 2 and 3. Lane and Kennedy (1988) suggest if means fall within the range of the upper three to four simulators, closer examination of the simulator is warranted. Simulator sickness is severe enough in the AH-1S to meet this criterion; the simulator is particularly high on the nausea and visuomotor subscales implicating perhaps both the visual and motion base systems in contributing to symptomatology.

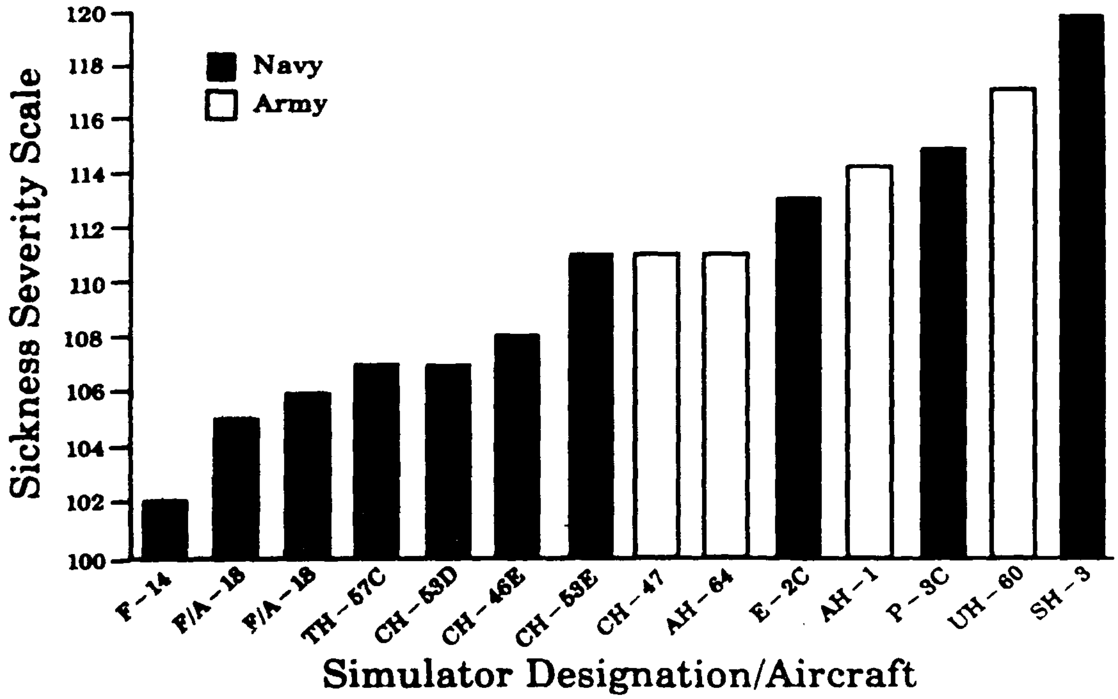


Figure 15. SSQ visuomotor subscale.

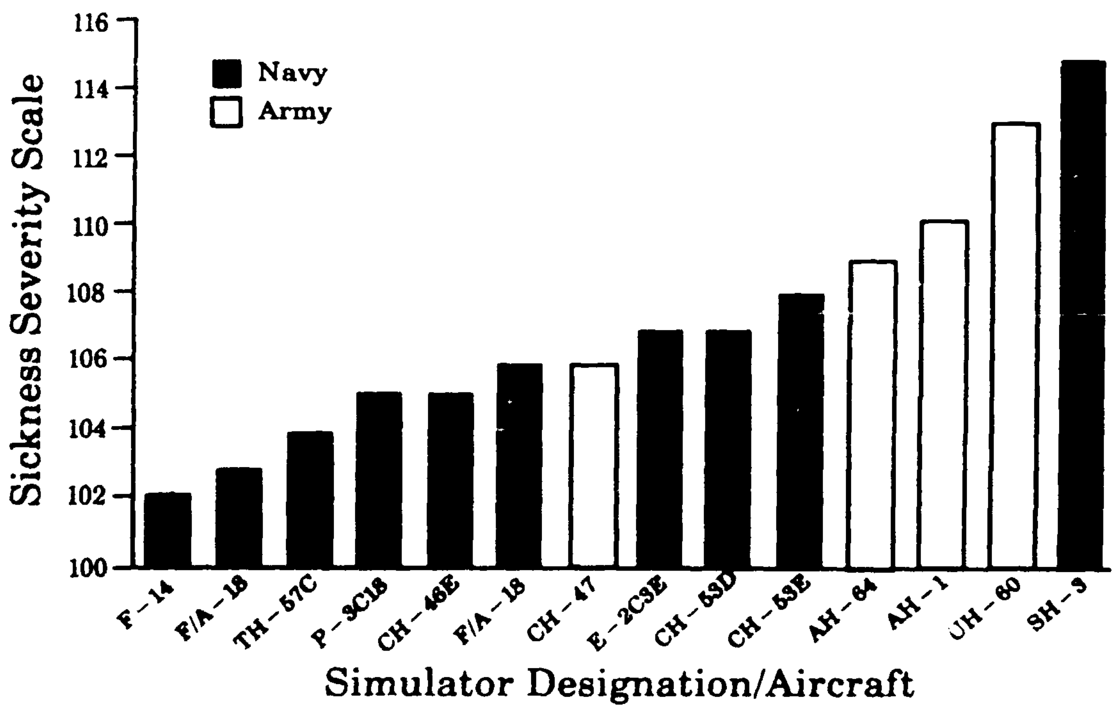


Figure 16. SSQ nausea subscale.

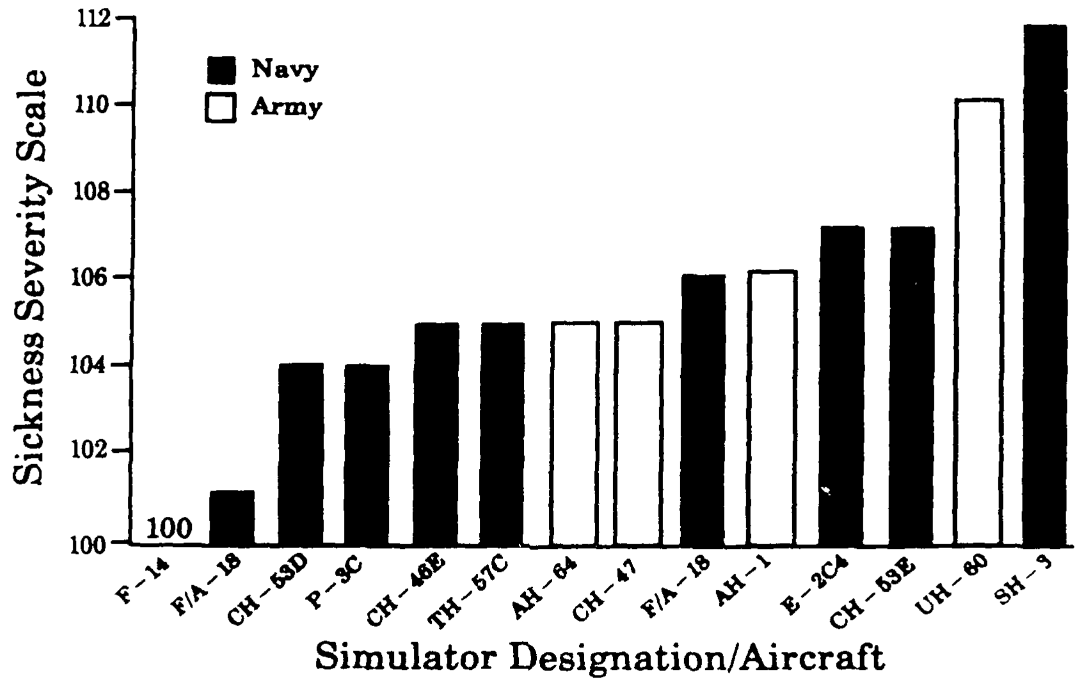


Figure 17. SSQ disorientation subscale.

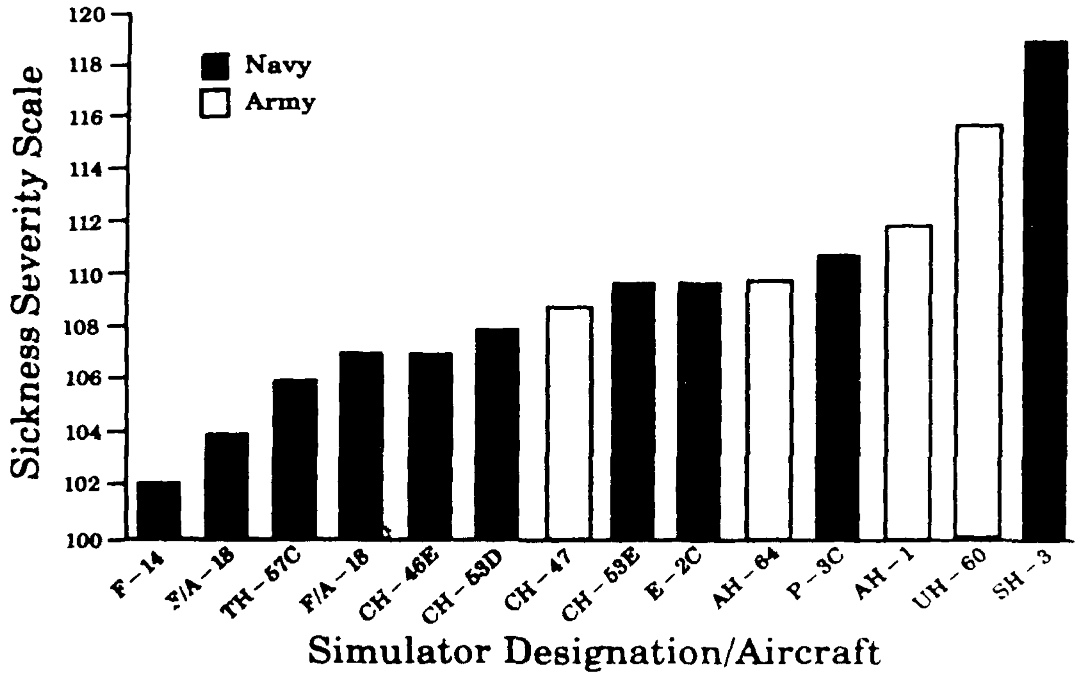


Figure 18. SSQ total severity score.

Postural stability

PET means and standard deviations, minimum and maximum scores, along with the results of paired measures t-tests are reported in Table 5. There were decrements in performance on both the "SOPLEC" and "SONLEC" tests, which reached statistical significance for the "SONLEC" test only. A reliable decrement on even one of the "PET" tests suggests that pilots' safety may be jeopardized after training in the simulator.

Table 5.

Means, standard deviations, minimum/maximum scores, and observations for pre- and post-WOFLEC, SONLEC, and SOPLEC measures.

	WOFEC		SONLEC		SOPLEC	
	Pre	Post	Pre	Post	Pre	Post
Mean	11.19	11.39	26.22	24.75	26.23	25.25
SD	1.53	1.58	7.47	8.17	7.14	8.02
Min-max	5.7-12	5.0-12	2.30-30	3.70-30	2.7-30	3.0-30
t(df), p value	*t*(83)= -.89	*p*=.378	*t*(83)= 2.52	*p*=.014	t(83)= 1.51	p=.13
Observations	84	84	84	84	84	84

Correlations

Table 6 shows correlations for pilot, simulator, and training variables with SSQ scores. Correlations were run against all variables which (1) could rationally be expected to be related to the criterion scores, and (2) were represented by adequate frequency distributions. Descriptions and coding of these variables appear in Appendix B. Only correlations that reached the .05 level of statistical significance were presented in the table.

Table 6.

Intercorrelations among variables
(85 total possible observations).

	SSQ Scores			
Pilot variables	N	V	D	TS
Simulator hours (last 3 days)		-.18		
Sleep		-.40	-.22	.31
Enough sleep		.30		.20
SOPLEC		.22	.20	
SONLEC	.40	.26	.27	.34
MHQ				
Simulator variables				
Sound on/off			-.26	
Other systems off		-.19		
Hours in seat		.22		
Percent upper air	.20	.34	.19	.29
Percent windows	.22	.21		.22
Night		.25		
Freeze	-.21		-.18	
Hits			.21	
Landings attempted		.24		
Visual disruptions		.20		
Visual traits	.19			
Training variables				
Different from aircraft	.50	.52	.44	.55
Discomfort hampers training	.40	.31	.30	.38

Pilot variables

Greater recent simulator experience was associated with lower symptomatology scores, suggesting that pilots with recent simulator experience may adapt to provocative stimuli that are part of the simulation. Inadequate sleep was associated with higher symptomatology scores, in keeping with the view that pilots who are not in their usual state of fitness may be more susceptible to simulator sickness. Nineteen percent of the sample rated their previous night's sleep as not enough. Pilots' ratings of whether they got enough sleep were related to symptomatology, suggesting this may be an easily obtained and useful predictor variable. Finally, SOPLEC and especially SONLEC PET scores were positively related to simulator sickness severity suggesting that aviators who experience the worst symptomatology are more at risk for postural disturbances. MHQ scores also were predictive of symptomatology.

Simulator variables

Correlations between "sound on/off" and "other systems off" with SSQ scores suggest, as the conditions of the simulation become more unlike the actual aircraft, the symptomatology increases. Although this is consonant with the cue conflict theory of motion sickness, the correlations are weak and should not be interpreted to indicate the guiding principle in simulator design should be toward increased fidelity in all systems.

The more time spent in upper air work was associated with higher symptomatology. The more time spent looking out the windows also was associated with more severe symptomatology. This would be expected. Indeed, a copying mechanism commonly used by pilots to reduce symptomatology is to go on instruments (Baltzley et al., 1989). Surprisingly, the more times the simulator was put on freeze, the lower the symptomatology. Generally, freeze is associated with simulator sickness (Kellogg, Castore and Coward, 1980; Kennedy et al., 1987a), especially if used improperly. However, if the freeze function is used after flying into the clouds or during straight and level flight, it might serve as a time out and, thereby, be associated with decreased simulator sickness.

Training under night flying condition was associated with increased symptomatology most probably because it was associated with NVG training. Greater number of landings was associated with increased severity of sickness, which may be due to the increase in near ground interaction which is thought to be nauseogenic (Kennedy et al., 1987a). Finally, noted disruptions in the visual system was associated with an increase in symptomatology.

There was an inadequate distribution of the "motion system on/off" variable to calculate a correlation (only two flights were conducted with the motion system off). However, it was the general consensus among pilots and instructor operators that flying the simulator with the motion system off was far more provocative.

Training variables

It can be seen that pilots who experienced greater symptomatology were more likely to rate their symptoms as being worse than those they experience in the actual aircraft. This is evidence that simulator sickness symptomatology is of greater severity than symptomatology experienced in the actual aircraft. Some pilots commented that their first experience of motion sickness was in a flight simulator.

Also, it can be seen that greater symptomatology is associated with a less favorable rating on whether simulator-induced discomfort disrupts training. A fuller appreciation of this relationship can be seen in Table 7 which shows the frequencies for this variable. The majority of pilots felt that simulator-induced discomfort does not hamper training. However, as the correlation indicates, those who experienced symptomatology tended to give a less favorable rating. While Table 7 indicates a strong and favorable opinion of the simulator, it can be assumed for those experiencing discomfort, their time, and the expense of the simulator are being under utilized.

Table 7.

Frequencies for variable
"discomfort hampers training"

Response	f	Percent
Strongly disagree	53	68.8
Tend to disagree	15	19.5
Neutral	3	3.9
Tend to agree	5	6.5
Strongly agree	1	1.3
Observations	77	

Symptomatology by mission and seat

Mission

Table 8 shows SSQ scores by mission flown. NVG training is associated with the most severe symptomatology followed by proficiency training. Not surprisingly, instrument training, associated with negligible out the window viewing (Table 9), is associated with the least severe symptomatology.

Table 8.

Mean (standard deviations) SSQ scores by mission.

SSQ scale	Proficiency	Instrument	Tactical	NVG
Nausea	114.6	104.8	110.0	114.3
Visuomotor	117.4	106.8	114.4	119.0
Disorientation	105.7	104.9	107.3	106.1
Total severity	115.8	106.6	113.0	116.6
Observations	17	20	21	16

Table 9.

Scenario content data (means and standard deviations) for different missions flown in the AH-1S simulator.

	Mission			
	Proficiency	Instrument	Tactical	NVG
Percent upper air	8.24	.50	10.00	18.94
Percent time out windows	71.65	23.85	79.50	81.50
Freeze	2.82	1.85	5.05	4.06
Hours in seat	1.85	2.00	1.64	2.44
Landings attempted	5.18	2.50	2.86	6.44
Observations	17	20	21	16

Seat

SSQ scores are broken out by seat in Table 10. Comparisons of severity of simulator sickness for pilots, copilot gunners, and for aircrew training in both seats show that pilots' training in the pilot seat and in both seats are at most risk for simulator sickness. A comparison of missions flown for these categories (Table 11) shows that 28.6 percent of aircrew training in the pilot and 17.9 percent of those training in both seats flew NVG missions compared to 0 percent of pilots flying in the copilot gunner seat which could account for the difference. As seen previously in Table 8, aircrews flying NVG missions experience severe symptomatology. Other key scenario variables also could contribute to the difference; aircrew training in the pilot and in both seats, on average, spent a greater percentage of the time looking out windows; and aircrew training in both seats, on average, spent a greater percentage of time in upper air work, shown in Table 6 to be provocative.

Table 10.

SSQ scores by seat

SSQ scale	CPG	Seat Pilot	CPG/P	IO
Nausea	106.7	112.3	114.7	104.8
Visuomotor	110.3	117.9	114.6	108.8
Disorientation	104.9	109.9	106.0	101.2
Total severity	109.0	116.3	114.6	106.5
Observations	17	28	28	12

Table 11.

Mission and scenario content data for copilot gunners and pilots

	CPG	Seat Pilot	CPG/P
Percent aircrew flying key missions:			
Proficiency	47.1	21.4	3.60
Instruments	35.3	32.1	14.30
Tactics	11.8	14.3	39.30
NVG	0.0	28.6	17.90
Means for key scenario variables:			
Percent upper air	7.06	7.50	18.14
Percent time out windows	53.12	65.11	63.82
Freeze	3.29	2.82	3.71
Hours in seat	1.71	1.85	2.09
Landings attempted	4.18	4.04	2.86
Observations	17	28	28

There were 12 observations of instructor operators. These data suggest, under the conditions of the simulation flights flown by these individuals, instructor operators are at low risk for simulator sickness. However, experimenter interviews with instructor operators revealed they experience symptomatology which is sometimes severe after flying several periods in the simulator or if they are not in their usual state of fitness.

Discussion

The principal goal in this field study was to assess the incidence of simulator sickness in this simulator. The results show that this simulator produces a higher incidence of simulator sickness than the two other Army visually coupled flight simulators, the CH-47 and the AH-64. As in other systems, eyestrain and headache were leading symptoms of asthenopia, while fatigue and sweating were leading symptoms associated with motion sickness. The high scores on the N, V, D, and TS scales rank the AH-1S in the top three of all simulators studied by the Army and the Navy.

The high scores are cause for concern and raise questions about the visual and motion base representation of flight experienced by the aviators in the AH-1S flight simulator. The tasks accomplished in this simulator require close coordination between the pilot and the copilot/gunner that should not be degraded because of the general discomfort of the aircrew due to simulator effects. Of concern to us is the relatively high percentage of instrument flights (32 percent for pilots and 35 percent for copilots) logged during this study. Such large percentages of time spent with no scene content would account for the lower SSQ scores flying those types of missions as seen in Table 8. If, in fact, the aviators are opting to fly under instrument conditions to avoid the discomfort associated with NVG or low-level flight, then there is cause for concern, especially in a simulator designed to train target acquisition and designation and engagement.

The use of NVGs in the AH-1S simulator is associated with higher scores on the SSQ as seen in Table 8. The NVGs in actual flight tend to cause problems due to their added weight, limited field-of-view, and degraded visual qualities. Moreover, because they restrict the field-of-view, NVGs may cause recalibration of the vestibulo-ocular reflex. When combined with the artificial environment of the simulator, it is not surprising to see a relatively higher incidence of visuomotor symptoms.

As stated in the methods section, the researchers did not exercise any control over the flights in the simulator. In the absence of detailed programs of instruction (POI) or standardized flight scenarios, it is very difficult to accurately describe provocative flight conditions. Further, the amount of adaptation during the flight and on subsequent flights is not assessed. The time course of the symptoms experienced also was not possible to assess in the study. Therefore, symptomatology may be underestimated for some earlier flights and overestimated for later flights. In general, the manner in which the questionnaires were scored tends to be conservative. These topics should be studied under controlled conditions.

The method of testing postural stability used in this study was successful in demonstrating post-exposure ataxia in a previous study (Gower et al., 1987). However, due to the operational considerations of the current study, none of the aviators received sufficient practice to reach a level of proficiency on the tests prior to simulator exposure. It is possible the lack of significant decrements on two of the three tests is due, in part, to the masking of simulator effects by practice effects. Experimenter records indicated that some aircrews felt unsteady after their simulator exposure but, nevertheless, performed well on the tests. Furthermore, poor performance on one scale is cause for concern and two of three scales showed a degradation in steadiness. Further controlled studies with stabilimeter measurement should be considered.

Anecdotal information received at USAARL from fielded AH-1S flight simulator sites has indicated that aviators flying regular missions in the AH-1S flight simulator have experienced delayed effects beyond the simulator flight itself. Some were reported to have occurred 2 and 3 days postexposure. This report was not able to assess the time course of the postflight symptomatology, however, the relative degree of severity and reports of other delayed symptoms is cause for a further look at the issue.

Recommendations

In view of the results of this study and other studies conducted in Army visually-coupled flight simulators, it is our recommendation that:

a. Continued caution be exercised with those aviators flying in this simulator. This also should include adherence to the 6-hour wait period advocated in USAARL Report No. 88-1.

b. Commanders should, in conjunction with their flight surgeons, implement monitoring of their aviators to assess those who have demonstrated problems with the simulator environment. Those who do experience problems should restrict flight in the actual aircraft for at least one night's rest to allow them to dissipate. Strict adherence to the guidelines published in Kennedy et al. (1987a) should be followed for aviators experiencing problems until they adapt to the simulator.

c. Calibration and alignment of the visuals be accomplished regularly and as a part of routine maintenance. Consideration should be given to having the visual system of this and other

Army simulators checked for excessive flicker, accommodation, and vergence demands, unequal accommodative demands, and accommodation/vergence conflict.

d. Further controlled studies be conducted to ascertain the role of aviator susceptibility and its part in the phenomenon of simulator sickness. These studies also may involve the use of psychophysiological measurements in order to determine objectively the time course of the aviator's simulator sickness experience. One question still not answered is the actual time course of the symptoms experienced by the aviators in the simulator and the recurrence of delayed effects. Anecdotal data continues to be received indicating there is a part of the aviation population that experience delayed problems beyond the simulator exposure and for periods of time that exceed 6 to 8 hours for approximately 8 percent of the population and 1-to-2 days for an even smaller population.

e. Studies be conducted to determine which scenarios are linked with simulator sickness and methods to prepare aviators to deal with those scenarios. A correlation of simulator sickness with actual flight experience under similar conditions should be determined in side-by-side studies conducted in the simulator and in the aircraft.

f. Studies be conducted to ascertain the period of time an aviator should wait postflight before piloting an actual aircraft or even driving a car.

g. Commanders and supervisors should review the POIs being flown in their particular simulator device against the required missions that should be flown in the device. If aviators are avoiding the simulator for reasons of simulator sickness, then a larger problem exists than is indicated in this report. The use of a visually-coupled flight simulator for instrument training should be a cause for concern if it reaches proportions above the requirements.

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Appendix A

Simulator sickness survey

Serial No.____________Date______________

SIMULATOR SICKNESS SURVEY

This is a survey of simulator aftereffects being conducted for the U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama, in cooperation with the Naval Training Systems Center. The purpose of the survey is to determine the incidence of simulator aftereffects such as nausea or imbalance occurring in visually coupled flight simulators (UH-60, AH-1 CH-47).

We appreciate your cooperation in obtaining information about this problem. The results of the study will be used to improve the characteristics of future simulators. Your responses will be held in confidence and used statistically. Although we ask for your name on this page, no information will be reported by name. This cover page will be removed and all data will be identified by the coded serial number above.

Your Name ____________________________________ Rank ____________________

Date ____ Unit ____________________

Instructor ___________________________________ (if in Qualification training)

Training Stage : Qualification _____________ Continuation _____________

Refresher _____________ AAPART (Check Ride)_________

Mission _____________

Oct 1988 Revision

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Serial No.__________ Date____________

MOTION HISTORY QUESTIONNAIRE

1. Approximately, how many total flight hours as pilot and co-pilot do you have? (in all aircraft, civilian and military time inclusive)

a. Fixed Wing ______

b. Rotary Wing ______

2. How often would you say you get airsick?

Always ____ Frequently ____ Sometimes ____ Rarely ____ Never ____

3. a. How many total flight simulator hours? ________ (all except SFTS)

b. How many flight hours do you have in this this simulator? _____

4. How much experience have you had at sea aboard ships or boats?

Much ____ Some ____ Very Little ____ None ____

5. How often would you say you get seasick?

Always ____ Frequently ____ Sometimes ____ Rarely ____ Never ____

6. Have you ever been motion sick under any conditions other than the ones listed so far? No ____ Yes ____

If "Yes," under what conditions? ______________________________________

____

7. In general, how susceptible to motion sickness do you feel you are?

Extremely ____ Very ____ Moderately ____ Minimally ____ Not at all ____

8. Have you been nauseated FOR ANY REASON during the past 8 weeks?

No ____ Yes ____ If "Yes," explain ___________________________________

____

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9. When you were nauseated <u>for any reason</u> (including flu, alcohol, etc.), did you vomit?

Easily ____	Only with difficulty ____	Retch and finally vomited with great difficulty ____

10. If you vomited while experiencing motion sickness, did you:

a. Feel better and remain so? ______
b. Feel better temporarily, then vomit again? ______
c. Feel no better, but not vomit again? ______
d. Other - specify ________________________________

____

11. If you were in an experiment where 50% of the subjects get sick, what do you think your chances of getting sick would be?

Almost certainly would ____	Probably would ____	Probably would not ____	Almost certainly could not ____

12. Would you volunteer for an experiment where you knew that: (Please answer all three)

a. 50% of the subjects did get motion sick? Yes ____ No ____
b. 75% of the subjects did get motion sick? Yes ____ No ____
c. 85% of the subjects did get motion sick? Yes ____ No ____

13. Most people experience slight dizziness (not a result of motion) 3 to 5 times a year. The past year you have been dizzy:

more than this ____ the same as ____ less than ____ never dizzy ____

14. Have you ever had an ear illness or injury which was accompanied by dizziness and/or nausea? Yes ____ No ____

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15. Listed below are a number of situations in which some people have reported motion sickness symptoms. In the space provided, check (a) your PREFERENCE for each activity (that is, how much you like to engage in that activity), and (b) any SYMPTOM(S) you may have experienced at any time, past or present. You may list more than one symptom for each activity.

SITUATIONS	PREFERENCE				SYMPTOMS													
	Like	Neutral	Dislike		Vomited	Nausea	Stomach Awareness	Increased Salivation	Dizziness	Drowsiness	Sweating	Pallor	Vertigo	Awareness of Breathing	Headache	Other Symptoms	None
Aircraft																	
Flight Simulator																	
Roller Coaster																	
Merry-Go-Round																	
Other Carnival Devices																	
Automobiles																	
Long Train or Bus Trips																	
Swings																	
Hammocks																	
Gymnastic Apparatus																	
Roller/Ice Skating																	
Elevators																	
Cinerama or Wide-Screen Movies																	
Motorcycles																	

* Stomach awareness refers to a feeling of discomfort that is preliminary to nausea

Serial No.__________ Date______________

16. If you have ever experienced simulator sickness or discomfort (or any other aftereffect):

   a. What simulator was it? ______________________________

   b. What were the symptoms? ______________________________

   ____

   c. If they went away and then came back, describe what events surrounded their return. ______________________________

   ____

   d. How long did they last immediately post-flight?______________

   e. How long did they last if they went away and then came back?________

   d. What do you think caused the problem?______________________

   ____

END OF MOTION HISTORY QUESTIONNAIRE

Serial No.__________ Date______________

PRE-FLIGHT BACKGROUND INFORMATION

Instructions: Please fill this page out BEFORE you go into the simulator. Fill in the blanks or circle the appropriate item.

1. Start time for your flight: ________ Expected length of flight ______

2. Seat you will be in for the simulator flight (Circle only one):

   Copilot Gunner (CPG) (AH-1 only)

   Copilot (CP)

   Pilot (P)

   Instructor/Operator (IO)

   CPG seat for first part of flight, then P seat

   P seat for first part of flight, then CPG seat

3. Type of mission: Proficiency / Instrument / Tactics / Other ____

4a. Aircraft flight hours last 2 months ________________

4b. How many days has it been since your last flight IN THE AIRCRAFT? ____

5a. Simulator flights last 3 months ______ Simulator hours last 3 days ____

6c. How many days has it been since your last flight IN THIS SIMULATOR? ____

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PRE-FLIGHT PHYSIOLOGICAL STATUS INFORMATION

Instructions: Please fill this out BEFORE you go into the simulator.

1. Are you in your usual state of fitness: YES NO

   If not, what is the nature of your illness (flu, cold, etc.)?

   ____

2. Please indicate all medications you have used in the past 24 hours:

   a) NONE ______________

   b) Sedatives or tranquilizers ______________

   c) Aspirin, Tylenol, other analgesics ______________

   d) Antihistamines ______________

   e) Decongestants ______________

   f) Other (specify): ____________________ ______________

3. Have you used any tobacco products:

   In the past 24 hours? YES NO

   In the past 48 hours? YES NO

4. Have you had any beverage containing alcohol:

   In the past 24 hours? YES NO

   In the past 48 hours? YES NO

5. How many hours sleep did you get last night? ________ (Hours)

   Was this amount sufficient? YES NO

GO TO NEXT PAGE

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PRE-FLIGHT SYMPTOM CHECKLIST

Instructions: Please fill this out BEFORE you go into the simulator. Circle below if the symptoms apply to you right now. (After your simulator flight, you will be asked these questions again.)

1.	General discomfort______	None	Slight	Moderate	Severe
2.	Fatigue______	None	Slight	Moderate	Severe
3.	Boredom______	None	Slight	Moderate	Severe
4.	Drowsiness______	None	Slight	Moderate	Severe
5.	Headache______	None	Slight	Moderate	Severe
6.	Eye strain______	None	Slight	Moderate	Severe
7.	Difficulty focusing______	None	Slight	Moderate	Severe
8.	a. Salivation increased______	None	Slight	Moderate	Severe
	b. Salivation decreased______	None	Slight	Moderate	Severe
9.	Sweating______	None	Slight	Moderate	Severe
10.	Nausea______	None	Slight	Moderate	Severe
11.	Difficulty concentrating______	None	Slight	Moderate	Severe
12.	Mental depression______	No	Yes		
13.	"Fullness of the Head"______	No	Yes		
14.	Blurred vision______	No	Yes		
15.	a. Dizziness with eyes open______	No	Yes		
	b. Dizziness with eyes closed______	No	Yes		
16	Vertigo______	No	Yes		
17.	*Visual flashbacks______	No	Yes		
18.	Faintness______	No	Yes		
19.	Aware of breathing______	No	Yes		
20.	**Stomach awareness______	No	Yes		
21.	Loss of appetite______	No	Yes		
22.	Increased appetite______	No	Yes		
23.	Desire to move bowels______	No	Yes		
24.	Confusion______	No	Yes		
25.	Burping______	No	Yes	No. of times	______
26.	Vomiting______	No	Yes	No. of times	______
27.	Other______				

* Visual illusion of movement or false sensations similar to aircraft dynamics, when not in the simulator or the aircraft.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

STOP HERE! The test director will tell you when to continue

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Serial No.__________ Date______________

POST-FLIGHT SYMPTOM CHECKLIST

Instructions: Circle below if any symptoms apply to you right now.

1.	General discomfort____________	None	Slight	Moderate	Severe	
2.	Fatigue____________	None	Slight	Moderate	Severe	
3.	Boredom____________	None	Slight	Moderate	Severe	
4.	Drowsiness____________	None	Slight	Moderate	Severe	
5.	Headache____________	None	Slight	Moderate	Severe	
6.	Eye strain____________	None	Slight	Moderate	Severe	
7.	Difficulty focusing____________	None	Slight	Moderate	Severe	
8.	a. Salivation increased______	None	Slight	Moderate	Severe	
	b. Salivation decreased______	None	Slight	Moderate	Severe	
9.	Sweating____________	None	Slight	Moderate	Severe	
10.	Nausea____________	None	Slight	Moderate	Severe	
11.	Difficulty concentrating______	None	Slight	Moderate	Severe	
12.	Mental depression____________	No	Yes			
13.	"Fullness of the Head"________	No	Yes			
14.	Blurred vision____________	No	Yes			
15.	a. Dizziness with eyes open____	No	Yes			
	b. Dizziness with eyes closed__	No	Yes			
16.	Vertigo____________	No	Yes			
17.	*Visual flashbacks____________	No	Yes			
18.	Faintness____________	No	Yes			
19.	Aware of breathing____________	No	Yes			
20.	**Stomach awareness____________	No	Yes			
21.	Loss of appetite____________	No	Yes			
22.	Increased appetite____________	No	Yes			
23.	Desire to move bowels________	No	Yes			
24.	Confusion____________	No	Yes			
25.	Burping____________	No	Yes	No. of times	_____	
26.	Vomiting____________	No	Yes	No. of times	_____	
27.	Other____________					

28. Would you describe the symptoms above as

SAME AS
WORSE THAN
NO DIFFERENCE

from flight in the actual aircraft under the same conditions you experienced in the flight just completed.

* Visual illusion of movement or false sensations similar to aircraft dynamics, when not in the simulator or the aircraft.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

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Serial No.____________ Date_______________

POST-FLIGHT INFORMATION

Instructions: Please fill out this page AFTER you have completed your flight.

1. The simulator was flown with the following systems ON/OFF:

Visual System	ON	OFF	DEGRADED
Motion System	ON	OFF	DEGRADED
Seat Shaker	ON	OFF	DEGRADED
Sound	ON	OFF	DEGRADED

2. Were any other systems turned off for a part of the flight? YES NO

   If YES, which system(s) ____________________________________

3. Were all the instruments that you needed for this flight operational?

   YES NO

4a. The collective control was: EXCELLENT/ GOOD/ FAIR/ BAD .

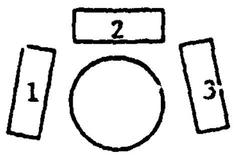
4b. The cyclic pitch control was: EXCELLENT/ GOOD/ FAIR/ BAD .

4c. The cyclic roll control was: EXCELLENT/ GOOD/ FAIR/ BAD .

4d. The anti-torque control was: EXCELLENT/ GOOD/ FAIR/ BAD .

5. Were any of the "windows" not on for the flight? YES NO

   If YES, which one? (Circle inoperable windows on diagram below)



6. How long did your flight period last? _____ Hours

7. Proportion (in percent) of the time spent: Low-Level ________

   Nap-of-the-Earth (NOE) ______ Upper Air Work: ______ Instrument______

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Serial No.____________Date_______________

8. Type of flight conditions: Night / Dusk / Instrument / DAY VFR /

9. Percentage of time looking out of windows ______________________

10. Percentage of time operating TSU heads down ____________________

11. Number of times the simulator was put on freeze ________________

12. Number of times any scene was replayed _________________________

13. Number of impacts/ near hits from enemy ________________

14. Number of impacts with ground: ___________

15. Number of landings attempted: ____________

16. The time now _____________

17. Did you have to wait long periods while in the simulator for any reason?

    YES _____ NO _____ If YES, how long? _______

18. In terms of training effectiveness, this simulator accomplishes its purpose of training me to be more proficient at flight skills?

    Please circle the number which most closely corresponds to your feelings about the statement above.

5	4	3	2	1
Strongly Agree	Tend to agree	Neutral	Tend to agree	Strongly Disagree

19. If you experienced discomfort of some degree in the simulator (enough to mark one or more of the Post-Flight Symptoms), did their severity hamper your training during the flight? Circle the number which most closely describes your experience in today's flight.

5	4	3	2	1
Complete Disruption		Moderate Disruption		No Disruption

20. Scene Disturbances:

    Describe any disruptive visual system problems that you observed:

    ____

    ____

Serial No.____________ Date_______________

Describe any bothersome visual traits you would like to see corrected:

____

____

Describe any disruptive motion system problems that you observed:

____

____

Describe any bothersome motion system traits you would like corrected:

____

____

Serial No. ____________ Date ______________

POSTURAL EQUILIBRIUM TEST DATA SUMMARY SHEET

BEFORE

WOFEC						X= ______
SOPLEC						X= ______
SONLEC						X= ______

AFTER

WOFEC						X= ______
SOPLEC						X= ______
SONLEC						X= ______

COMMENTS:

PREFERRED LEG- LEFT____ RIGHT____

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Appendix B

Variable descriptions

Variable	Description	Code
Pilot variables		
Simulator hours--3 days	Number of simulator hours in the last 3 days	Number of hours
Sleep	Hours sleep previous night	Hours sleep
Enough sleep	Was the amount of sleep previous night sufficient?	1=Yes, 2=No
MHQ	Motion History Questionnaire susceptibility score	Range: 0 to +68 0 = low susceptibility
SONLEC/SOPLEC	Pre- minus post score	
Sound on/off	Sound on or off during flight	1=On 2=Off/Degraded
Other systems off	Were other systems off during the flight?	1=Yes, 2=No
Hours in seat	Length of flight	Length of flight (hours)
Percent upper air	Percent of flight spent in upper air work	Percentage
Percent windows	Percent of time spent looking out windows	Percentage
Night	Night flight conditions	1=Yes, 0=No
Freeze	Number of times simulator put on freeze	Number of times
Landings attempted	Number of landings attempted	Number of landings
Visual disruptions	Notice any disruptive visual system problems?	1=Yes, 2=No
Visual traits	Are there bothersome visual traits that need correcting?	1=Yes, 2=No

Training variables	Description	Code
Different from aircraft	Are symptoms experienced the same or worse than those experienced in the actual aircraft?	1=Same, 2=Worse
Discomfort hamper training	Discomfort experienced hampered training	1=Strongly disagree 2=Tend to disagree 3=Neutral 4=Tend to agree 5=Strongly agree

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Support Activity
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MD 21701

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Institute of Infectious Diseases
Fort Detrick, Frederick,
MD 21701

Director, Biological
Sciences Division
Office of Naval Research
600 North Quincy Street
Arlington, VA 22217

Commander
U.S. Army Materiel Command
ATTN: AMCDE-XS
5001 Eisenhower Avenue
Alexandria, VA 22333

Commandant
U S. Army Aviation
Logistics School
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Cleveland, OH 44135

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Wright-Patterson AFB, OH 45433

U.S. Air Force Institute
of Technology (AFIT/LDEE)
Building 640, Area B
Wright-Patterson AFB, OH 45433

University of Michigan
NASA Center of Excellence
in Man-Systems Research
ATTN: R. G. Snyder, Director
Ann Arbor, MI 48109

Henry L. Taylor
Director, Institute of Aviation
University of Illinois-
Willard Airport
Savoy, IL 61874

John A. Dellinger,
Southwest Research Institute
P. O. Box 28510
San Antonio, TX 78284

COL Craig L. Urbauer, Chief
Office of Army Surgeon General
National Guard Bureau
Washington, DC 50310-2500

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St. Louis, MO 63120

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Commanding Officer
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Sixth U.S. Army
ATTN: SMA
Presidio of San Francisco,
CA 94129

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Department of Human Factors
ISSM, USC
Los Angeles, CA 90089-0021

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Ames Research Center
MS 239-5
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of Research
ATTN: Medical Research Library
Presidio of San Francisco,
CA 94129

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Naval Biosciences Laboratory
Naval Supply Center, Bldg 844
Oakland, CA 94625

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U.S. Army Medical Materiel
Development Activity
Fort Detrick, Frederick,
MD 21701-5009

Commander, U.S. Army
Aviation Center
Directorate
of Combat Developments
Bldg 507
Fort Rucker, AL 36362

Chief
Army Research Institute
Field Unit
Fort Rucker, AL 36362

Commander
U.S. Army Safety Center
Fort Rucker, AL 36362

U.S. Army Aircraft Development
Test Activity
ATTN: STEBG-MP-QA
Cairns AAF
Fort Rucker, AL 36362

Commander
U.S. Army Medical Research
and Development Command
ATTN: SGRD-PLC (COL Sedge)
Fort Detrick, Frederick
MD 21701

MAJ John Wilson
TRADOC Aviation LO
Embassy of the United States
APO New York 09777

Directorate
of Training Development
Bldg 502
Fort Rucker, AL 36362

Chief
Human Engineering Laboratory
Field Unit
Fort Rucker, AL 36362

Commander
U.S. Army Aviation Center
and Fort Rucker
ATTN: ATZQ-T-ATL
Fort Rucker, AL 36362

President
U.S. Army Aviation Board
Cairns AAF
Fort Rucker, AL 36362

Dr. William E. McLean
Human Engineering Laboratory
ATTN: SLCHE-BR
Aberdeen Proving Ground,
MD 21005-5001